The Many-Worlds Interpretation of Quantum Mechanics
Current Status and Relation to Other Interpretations

Abstracts

Yakir Aharonov
Solving the Measurement Problem without Many Worlds

I will show how a definite result of a measurement can be fully determined when considering specific forward- and backward-evolving quantum states. Moreover, the macroscopic time reversibility is attained at the level of a single branch of the wavefunction when several conditions regarding the final state and dynamics are met. These entail a renewed perspective on the measurement problem, the Born rule and the many-worlds interpretation.

Valia Allori
Many-Worlds and Scientific Realism

The many-worlds theory is a theory which, according to their proponents, solves the measurement problem of quantum mechanics in the simplest, most straightforward way: no modification to the Schrödinger equation, no additional variables, not much of a change in anything a standard physicist would do. All this, but with the advantage of being able to be used by the scientific realist as a guide to the ontology of the world. In this paper I wish to argue that this is too good to be true: I show that the type of scientific realism that the supporter of the many-worlds theory is committed to accept is too close to instrumentalism than they would want. This is a consequence of focusing too much on the measurement problem, which I show is fundamentally a problem of empirical adequacy, while a scientific realist should be interested in more than this.

Mateus Araújo
Bell's theorem, Many-Worlds, and quantum key distribution

It is often argued that Bell's theorem simply does not apply to the Many-Worlds interpretation, as it implicitly assumes that measurements have single outcomes. While true, this is rather shallow. Can't we learn anything from Bell's theorem in the Many-Worlds interpretation? Here we show that we can. First we generalize Bell's local causality assumption to allow for multiple outcomes, and show that Many-Worlds does satisfy this generalized condition. Then we show that if in addition we assume that the result of a measurement is predictable, we can nevertheless derive a Bell inequality. Therefore, in Many-Worlds the violation of a Bell inequality certifies the fundamental unpredictability of the result of a measurement. This provides a natural explanation for the security of quantum key distribution.

Nathan Argaman

Future-Input Dependence as an Interpretation of Quantum Mechanics

It is well known that locality in Quantum Mechanics is an intricate issue. While faster-than-light signaling is impossible, quantum nonlocality is manifest in violations of Bell inequalities. Similar intricacies involving the arrow of time are seldom considered. Once this is appreciated, the following possibility presents itself: the degrees of freedom underlying quantum phenomena may not be subject to the standard (strong) arrow-of-time condition, despite the fact that they can only be used to signal from the past to the future (the signaling arrow of time is maintained). Exploring this possibility requires an all-at-once, block-universe, approach (as for path integrals). In some specific cases, including the setups pertaining to Bell and Leggett-Garg inequalities, alternative "realistic" descriptions of quantum phenomena have emerged. In these descriptions, the degrees of freedom ("hidden variables") pertaining to a certain time generically depend on the settings of the measurements to be made at a later time: they exhibit future-input dependence. This approach suggests novel resolutions to the mysterious aspects of Quantum Mechanics. In the talk, these resolutions will be compared to those of the MWI.

Marcus Arvan

Reinterpreting the Many-Worlds Interpretation of Quantum Mechanics: Dead Reckoning and the P2P Simulation Hypothesis

This paper argues that the Many Worlds Interpretation (MWI) has not received consensus support because it appears to violate plausible empiricist principles requiring scientific theories to be directly confirmable and/or disconfirmable by observational evidence--which the MWI appears to preclude insofar as observers can in principle only directly observe our 'world.' The paper then argues that a new reinterpretation of the MWI--the Peer-to-Peer Simulation Hypothesis and computer science and mathematics of 'dead reckoning'--together provide an elegant interpretation of what the many 'worlds' of MWI are, and in a manner that not only provides strong observational evidence for the MWI, but also a deeper computational networking explanation, far beyond the traditional interpretation of the MWI (or any other interpretation of quantum mechanics for that matter), for why our reality has its many strange quantum mechanical features in the first place.

Per Arve

The ontology of the Many-Worlds theory

There has been an extensive debate concerning the possibility of the wavefunction being ontic. Wallace has argued against this proposal and together with Timpson proposed the Space Time State being the proper ontology of the Many-Worlds theory. Their suggestion misses to include the existence of entanglement between particles localized at different points in ordinary space. As entanglement is an indefeasible feature it has to be included as a possible property of what is ontic. This is especially true when the branching structure is understood as an effect of decoherence, that is multiple entanglements. A better ontology is given by the gauge invariant features of the wavefunction, the wavefunction absolute squared and the current field in the configuration space as well as the total spin state. This suggestion is supported by Vaidman's view of the wavefunction absolute squared being the measure of existence.

Charles Bédard

Teleportation Revealed

Quantum teleportation demands to explain how real-valued parameters encoding the state at Alice's location make their way to Bob's location with only two bits of classical communication. An explanation in the Schrödinger picture will always have loose ends because it does not admit a local description of quantum systems. The Heisenberg picture solves the problem neatly, highlighting the quantum nature of the classical.

Tomasz Bigaj

Consistent histories and many worlds

Two fundamental features of the many worlds interpretation are: the privileged status of the universal wave function as the only fundamental beable, and the deterministic evolution thereof (Vaidman 2021). In contrast to that, the consistent histories approach treats wave functions purely instrumentally as pre-probabilities, and stresses the stochastic character of quantum processes (Griffiths 2002, 2013). The unitary evolution of the wave function constitutes only one possible history out of many alternative histories. A unitary family of histories is special in that it assigns only probabilities 0 or 1 to individual histories, whereas histories based on incompatible projectors are assigned non-trivial probabilities, and thus are not deterministic. It is stressed that no history, whether deterministic or probabilistic, has the privileged status of being the "real" one. Hence on the face of it the consistent histories approach is clearly non-Everettian. And yet many authors insist that the consistent histories formalism "does Everett nicely", to use Simon Saunders' expression (Saunders 2010, see also Hartle 2010, Halliwell 2010, Wallace 2012). Characteristically, an appeal to the consistent histories approach is made in the context of the problem of quasi-classicality (the emergence of the classical features of the world) and the role of decoherence in selecting an approximately classical evolution of the world. But doesn't this analysis contradict the Principle of Equality, which states that all individual frameworks (histories) are equally acceptable? In this talk I will analyze the apparent conflict between the Everettian conception and the consistent histories approach. I will pose the question which of the fundamental assumptions of these conceptions have to be abandoned or relaxed in order to combine them together into one coherent theory.

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Eddy Keming Chen

Strong Determinism

A strongly deterministic theory of physics is one that permits exactly one possible history of the universe. In the words of Penrose (1989), "it is not just a matter of the future being determined by the past; the entire history of the universe is fixed, according to some precise mathematical scheme, for all time." Such an extraordinary feature may appear unattainable in any realistic and simple theory of physics. In this paper, I propose a definition of strong determinism and contrast it with those of standard determinism and super-determinism. Next, I discuss its consequences for explanation, causation, prediction, fundamental properties, free will, and modality. Finally, I present the first example of a realistic, simple, and strongly deterministic physical theory--the Everettian Wentaculus. As a consequence of physical laws, the history of the Everettian multiverse could not have been different. If the Everettian Wentaculus is empirically equivalent to other quantum theories, we can never empirically find out whether or not our world is strongly deterministic. Even if strong determinism fails to be true, it is closer to the actual world than we have presumed, with implications for some of the central topics in philosophy and foundations of physics.

Michael Cuffaro

Everett, the Informational Interpretation, and the Open Systems View

The traditional metaphysical picture of the physical world takes observer-independent _properties_ as primary and to be the origin of _values_ of dynamical quantities revealed in experiments. This picture is naturally suggested by classical mechanics, since the classical state fixes the values of all such quantities in advance. Famously, however, this is not true of the quantum state. Everett is the most natural interpretation of quantum mechanics given the metaphysical picture just described, for since the values of quantum-mechanical observable quantities cannot be consistently interpreted as representing observer-independent properties of a single classically describable physical system, the lesson, given that picture, that one should draw, is that we should consider all of the (approximately) classical possibilities relating to the system to be realized. Despite this, one reason that Everett is not the consensus interpretation is that there are legitimate reasons to reject the traditional metaphysical picture of the world just described. On the informational interpretation, for example, what is preserved from classical mechanics is not the _metaphysical_ picture it suggests, but the _methodology_ that takes values to be primary and considers them under the constraints imposed on them by theory. A priori, the question of how to conceive of reality, on the informational interpretation, is an open one, and the answer suggested by quantum mechanics is that a conception of the ontology of the world that does not include a reference to the possibilities of observation is inadequate for physics. In this talk I will compare the Everett and Informational interpretations of quantum mechanics from the viewpoint that takes an, in general, non-unitarily evolving density operator to be the fundamental vehicle of representation in quantum theory.

Erik Curiel

What Happens to EPR Correlations among the Many Worlds in Curved Spacetime?

What happens to the correlations among the spatially directed correlated properties of entangled quantum particles (e.g., spin for electrons in the singlet state) as they propagate apart in curved spacetime is, to the best of my knowledge, an almost entirely unexplored problem. In a curved spacetime, there is in general no canonical or preferred way to compare spatial directions at separated spacetime points. It is thus not even clear what it means to say that a pair of electrons initially in the singlet state do or do not remain in that state as they propagate away from each other in a curved spacetime. I will try to sharpen the question, and propose some ideas for what a possible solution might look like in the Many Worlds Interpretation."

Jan Dziewior

Variants of Locality and Causality in Many Worlds

A *single world assumption* is always at least an implicit part of any formulation of Bell's theorem and thus Many World Interpretations (MWI) are taken to trivially provide models which allow to explain Bell correlations without having to give up any of the remaining assumptions, in particular preserving locality. However, since these interpretations differ significantly, especially with respect to the concept of "world" and the corresponding fundamental ontology, it is to be expected that they also provide decidedly different versions of the physical scenario underlying Bell's theorem leading to different accounts of the causal relationships between the occurring events. This talk attempts to give an overview of the similarities and differences between the various versions of the MWI in particular with respect to the Bell scenario. It aims to sketch the different ontologies and concepts of locality and based on this, to present a discussion of the different causal stories told by the various interpretations both with respect to a particular world as well as to the entire universe.

Avshalom Elitzur

Do Parallel Worlds Leave Causal Traces in One Another?

IFM has revealed the causal potency of non-events. A detector click that did not occur leaves causal effects just because it *could* occur. Within MWI, this causal curiosity is offered a natural explanation. Later experiments have revealed reciprocal effects of the undetected particle on the "detector." For example, a pair of excited and ground-state atoms that apparently did not exchange a photon become entangled just because the exchange was possible. Within the Two State-Vector Formalism, such non-events are offered a one-world account in the form of double exchange of “ghost” particles, one ordinary and the other with negative mass, posing a challenge to the MWI. I compare these Many- and One-World accounts and argue in favor of the latter.

Paolo Faglia
Non-Separability, Locality and Criteria of Reality in Everettian Quantum Mechanics

Using a 'reformulation of Bell's theorem', Waegell and McQueen (2020) argue that any theory that is local and does not involve retro-causation or fine-tuning must be a many-worlds theory. They then analyze several prominent many-worlds interpretations and conclude that wavefunction-based ontologies involve superluminal causation due to their non-separability, as opposed to the separable 'Parallel Lives' theory (Brassard and Raymond-Robichaud 2013, 2017, 2019; Waegell 2017, 2018).
I put forward two contentions. I first argue that the theorem fails, because it does not account for interpretations that are both non-separable and local. In support of this, I refute their claim that non-separable ontologies (e.g. wavefunction-based ontologies) involve superluminal causation, by defending the locality of the decoherence-based Everettian interpretation (e.g. Wallace 2012). I close with some doubtful remarks about separable Everettian interpretations such as 'Parallel Lives' and Deutsch-Hayden as compared to non-separable ones.

Nicolas Gisin
Many-Worlds in Classical Mechanics

Classical mechanics is usually considered as deterministic, including in chaotic systems. The usual view is that everything is coded in the initial conditions, as if God had played all dice at the big-bang and coded all outcomes in the real numbers that represent the initial conditions. However, there is an alternative view with exactly the same empirical power. In this alternative view, one assumes that the initial conditions are not faithfully represented by real numbers (which typically contain infinite information), but by intuitionistic mathematics numbers (which always contain only finite information). The later numbers evolve as time passes, as if God plays the dice when new information is needed, e.g. when in chaotic systems the indeterminacy becomes too large. This view of classical mechanics has the advantage of bringing classical closer to quantum mechanics. Both have some indeterminacy and both are indeterministic. Hence, one can distinguish those features of quantum physics which are merely due to indeterminism from those intrinsically quantum. For example, the many-worlds view is not specific to quantum theory, but can equally be adapted to indeterministic classical mechanics. Also, some form of entanglement and of "collapse without signalling" (reduction of indeterminacy) can be introduced in classical mechanics. However, the absence of incompatible physical quantities (observables) makes it impossible to violate Bell inequalities in classical mechanics.

Guy Hetzroni

Consensus, theoretical virtues and interpretation: lessons from past debates

Prominent physicists have advocated the many worlds interpretation by describing the lack of consensus regarding the interpretation of quantum theory as problematic or embarrassing, and on the other hand highlighting the role of determinism, locality and unitarity. In my talk I will reflect on the question of whether such a consensus is indeed desirable at this point by comparing the interpretational debates on quantum theory with past interpretational debates, focusing on the role of theoretical virtues. Adopting a pragmatic point of view towards theory choice, I'll argue that past debates show that the attempt to achieve consensus on metaphysical questions based on theoretical virtues is not scientifically fruitful. The first example to be examined is the debate about the ontology of space in classical mechanics, understood retrospectively in light of the discovery of the general theory of relativity. The second is about the ontology of classical electromagnetism understood in light of the discovery of the Aharonov-Bohm effect. Both examples show, I argue, that interpretational debates can in some cases be seen as an indication of an open question within physics. A debate that seems purely interpretational within a given theory, becomes physically significant in the context of unification, and lack of agreement is beneficial in order to explore different theoretical possibilities. The measurement problem is accordingly best understood as a scientific problem that urges us to re-examine our theories and the interface between them, rather than as a merely interpretative issue or a problem in our understanding. The many worlds interpretation has a central role in this project.

Andrew Jordan

Quantum erasing the memory of Wigner's friend

A variation of Wigner's gedankenexperiment, introduced by Frauchiger and Renner, has lead to new debates about the self-consistency of quantum mechanics. At the core of the paradox lies the description of an observer and the object it measures as a closed system obeying the Schrödinger equation. We then propose a simple single-photon interferometric setup implementing Frauchiger and Renner's scenario, and use the derived condition to shed a new light on the assumptions leading to their paradox. From our description, we argue that the three apparently incompatible properties used to question the consistency of quantum mechanics correspond to two logically distinct contexts: either one assumes that Wigner has full control over his friends' lab, or conversely that some parts of the labs remain unaffected by Wigner's subsequent measurements. The first context may be seen as the quantum erasure of the memory of Wigner's friend.

Adrian Kent

Many Worlds and the Limits of Science

Along with several other critics, I have argued that many-worlds quantum theory would not be scientifically confirmable even if correct. Many-worlds proponents tend to counter by arguing that the underlying issue is the interpretation of probabilities and that the same problems arise in probabilistic one-world theories. I will review the state of these debates and argue (i) that the problem of probabilities in many worlds cannot be separated from the problem of structure, and that some of the best known proposals for addressing the former fail to give a coherent and consistent account of the latter (ii) that there is a scientific methodology for confirming one-world theories that does not extend to many-worlds theories.

Samuel Kuypers

Everettian Relative States in the Heisenberg Picture

Everett's relative-state construction has nearly always been expressed in the Schrödinger picture, which is a non-local description of quantum systems. Therefore, Everettian universes appear to 'split' superluminally during measurements in entangled systems.

In contrast, the Heisenberg picture is a local description. In this talk, I will provide a review of the Heisenberg picture and formulate Everett's construction within that picture. The result is a construction which, unlike Everett's one in the Schrödinger picture, makes manifest the locality of Everettian multiplicity, its inherently approximative nature, and its origin in certain kinds of locally inaccessible information. The Heisenberg-picture construction also provides a more precise definition of an Everett 'universe', under which it is fully quantum, not quasi-classical.

Dustin Lazarovici

Why Everett Solved the Probability Problem

The proposed talk will defend Hugh Everett's typicality argument for the Born rule in light of the recent literature on typicality – in particular, against the circularity objection that has led to its dismissal by most contemporary Everettians.

Zhonghao Lu

Personal Identity and Uncertainty in Everett's Multiverse

The deterministic nature of EQM seems to be inconsistent to the probability talk in EQM, and this is called the "incoherence problem". Sanders and Wallace try to invoke the Lewisian account of personal identity to solve the incoherence problem. In my paper, I clarify the objections to their solution and illustrate the only two interpretations of their solution. I argue that, if there is only one 3-dimensional entity of each type which supervenes on one single physical state, their solution would fail to solve the incoherence problem. Consequently, there should be more than one 3-dimensional entity of at least one type which supervenes on one single physical state. I further argue that this remaining interpretation is inconsistent with physicalism. This suggests us to pay more attention to issues of personal identity and possible non-physicalism interpretations of EQM.

Lorenzo Maccone

Quantum Time, Quantum Spacetime and Time Measurements

We consider a quantum block universe in which also the time degree of freedom is quantized. We both look at the Galilean (non-relativistic) case (Schroedinger equation) and at the covariant relativistic case. The quantization of time is necessary to appropriate describe time measurements in quantum mechanics.

Tim Maudlin

Local Beables, Wave Function Monism, and Empirical Content

In order to make empirically testable predictions, a proposed physical theory must somehow have implications for the sorts of things we take ourselves to have empirical access to. John Bell defended the proposal that the standard and clearest way to secure such a connection is via the postulation of *microscopic local beables in a familiar space-time,* i.e. a space-time the is at least macroscopically four-dimensional. This poses a challenge for any theory that does not posit such microscopic local beables: either it must explain how such beables (and the space-time they inhabit) emerge from something else, or else it must explain how to do without local beables at all. Since the standard accounts of the Many Worlds theory purport to be monistic (i.e. only to postulate a "wave function", or an object directly represented by a wave function), and since the wave function is not (or does not seem to represent) a local beable in 4-dimensional space-time, Many Worlds approaches must confront this issue in order to have any empirically testable consequences at all. I will argue that as yet they have failed to do so.

Alyssa Ney

Locality and the Metaphysics of Many Worlds

Some think the Many Worlds Interpretation (MWI) is to be preferred over other solutions to the measurement problem because it provides a local interpretation. However, the locality of MWI appears to depend on the way MWI is itself interpreted metaphysically. This paper defends the locality of several metaphysical interpretations of MWI against recent criticisms.

Don Page

Possibilities for Probabilities

In ordinary situations involving a small part of the universe, Born'srule seems to work well for calculating probabilities of observations in quantum theory. However, there are a number of reasons for believing that it is not adequate for many cosmological purposes. Here a number of possible generalizations of Born's rule are discussed, explaining why they are consistent with the present statistical support for Born's rule in ordinary situations but can help solve various cosmological problems.

David Papineau and Thomas Rowe

How the MWI Matters: Relief, Regret and Distributive Justice

At first pass, Everettian metaphysics requires no alteration to the way agents make decisions. Everettian agents, just like orthodox ones, will aim to maximise utility on weighted average over future outcomes (even if they view the metaphysical import of the relevant weights rather differently). Still, Everettianism does have some consequences for decisions.
(1) For a start, it refashions backward-looking evaluations of actions like regret and relief. On orthodoxy, it can make sense to regret a rational decision that “turns out” be unsuccessful, and to feel relief about an irrational decision that “turns out” to do no harm. But Everettians will have no room for these reactions, given that they do not view risky decisions as having a single actual outcome.
(2) More substantially, Everettianism can make a difference when equity conflicts with aggregate utility. Consider an indivisible good on which Ann and Bob have unequal claims. Should the good be allocated by a random lottery with chances in proportion to their unequal claims? On orthodoxy, this looks wrong – the chances might then be allocated fairly, but Ann and Bob care only about the actual good, not mere chances therefore. On Everettianism, by contrast, there seems every reason to hold the lottery, since it will spread the real good fairly over Ann’s and Bob’s multiple successors in proportion to their respective claims.

Phil Pickering

Nonseparability in the Many Worlds Interpretation

While there is a consensus that the Many World Interpretation (MWI) of quantum mechanics (QM) does not imply action at a distance, many supporters concede that entanglement implies nonlocality of a different type: nonseparability. The state of two systems is nonseparable if the joint state does not supervene on the states of the systems individually. I defend the view that under the MWI, entangled system states are just as separable (or nonseparable) as joint states describing spatiotemporal properties in general relativity (GR). I review spatiotemporal joint states in GR, including the fact that they are only well-defined with respect to a parallel transport map, which does not supervene on the states of the individual systems. I show how the joint states of entangled quantum systems are directly analogous, albeit with a mapping function determined by the systems' interactions with other systems (a "measurement map"). I describe how individual system states in both GR and QM can be represented as well-defined geometric objects from a global perspective but not from a local perspective, and how our choice of perspective determines whether we consider such objects to be (non)separable. I conclude by explaining why single world theories of QM cannot appeal to a similar argument.

Francois-Igor Pris

A Wittgensteinian demystification of an Everettian interpretation of quantum mechanics

It can be argued that if we commit ourselves to classical realism and classical logic we are forced to adopt an Everettian interpretation of quantum mechanics. But we cannot adopt it without substantial philosophical and physical qualifications. Nevertheless the classical metaphysical realism can be modified. We suggest an interpretation of quantum mechanics within a Wittgensteinian contextual realism, which is indeed a demystified version of the Everett interpretation.The quantum theory is a Wittgensteinian rule. The «gap» between this rule and a concrete result of measurement is closed pragmatically (the measurement problem is dissolved). The Everettian branches-worlds are possible (not actual) applications of the theory-rule. The suggested deduction of the Born rule from the deterministic part of quantum mechanics, the most general principles of rationality and the symmetry principles means that in a sense the Born rule is implicit in the formalism of quantum mechanics taken in its application. A complicated theory of the Everettian interpretation of quantum mechanics, developed by David Wallace, is the price to pay for refusing to modify the doctrine of metaphysical realism.

Renato Renner

A theorem about many-worlds branches

According to the many-worlds interpretation of quantum theory, a quantum measurement generally leads to a splitting of the world into a number of branches, in each of which one of the possible measurement results is observed. In more complex setups, e.g., in an erasure experiment, one may not only have splitting but also merging branches. This raises the question whether one may, at least in principle, come up with a consistent characterisation for when worlds split and merge. In this talk I will present a theorem that points to the difficulties of this endeavour.

Michael Ridley

Quantum Probability from Temporal Structure

The Born probability measure describes the statistics of measurements in which observers self-locate themselves in some region of reality. In ψ-ontic quantum theories, reality is directly represented by the wavefunction. We show that quantum probabilities may be identified with fractions of a universal multiple-time wavefunction containing both causal and retrocausal temporal parts. This wavefunction is defined in an appropriately generalized history space on the Keldysh time contour. Our deterministic formulation of quantum mechanics replaces the initial condition of standard Schrödinger dynamics with a network of `fixed points' defining quantum histories on the contour. The Born measure is derived by summing up the wavefunction along these histories. We then apply the same technique to the derivation of the statistics of measurements with pre- and post-selection.

Jerome Romagosa

Unlucky Branches: (Dis)confirmation in Many Worlds

MWI entails the existence of unlucky branches: parts of the universe (or multiverse) in which experimentally observed outcome distributions differ substantially from the outcome distributions that quantum mechanics would have us predict. My interest lies in using unlucky branch thought experiments to explore David Albert's (2015) claims that Everettian quantum mechanics (i) is insusceptible to ordinary confirmation and disconfirmation, and (ii) cannot make sense of our sense of surprise when observing a set of low-probability experimental results. I offer a perdurantist approach to Lev Vaidman's self-locating uncertainty in order to explain the sense of surprise. I then demonstrate that some inhabitants of unlucky branches may find themselves facing a rational antinomy with respect to whether they ought to take their observations to confirm or disconfirm the MWI.

Mark Rubin

Locality and Deutsch-Hayden Quantum Field Theory

Bell’s theorem forbids the standard Copenhagen interpretation from providing a local mechanism to explain correlations between results of spatially separated quantum measurements. The Everett interpretation evades Bell's theorem and, in addition, provides a conceptual framework for such a local mechanism. Quantum field theory in the Deutsch-Hayden representation can provide an explanation for correlations which is effectively local. We outline the construction of the Deutsch-Hayden representation for nonrelativistic fermionic quantum field theory as well as an effectively local calculation of EPRB correlations and a manifestly separable calculation of spin correlations of entangled identical particles.

Simon Saunders

Decoherence-based branch-counting implies the Born rule

Realism about macroscopic experiments in the Everett interpretation shows that branching arises with decoherence and is pervasive, but the question ‘how many branches?’ is usually met by the answer that the question has no sense – the numbers are vast, but yet physically meaningless. However, as Boltzmann showed in the 1870s, *ratios* in numbers of microstates still make sense. The same method, applied to ratios in numbers of branches, implies the Born rule. This work is based on **https://doi.org/10.1098/rspa.2021.0600**, available at https://arxiv.org/pdf/2201.06087.pdf

Ovidiu Cristinel Stoica

The relation between wavefunction and 3D space

The wavefunction can be represented in terms of 3d-space fields, and has a 3d-space or spacetime interpretation from group-theoretic perspective. But the relation between wavefunction and 3d space is better understood in the wavefunctional formulation, especially in background-free quantum gravity. Background-freedom implies that most linear combinations of state vectors cannot be interpreted physically as superpositions, due to the absence of a common background. This leads automatically to the dissociation of the wavefunctional in states with definite 3d-space geometry. At micro scales, the dissociation is reversible, and at macro scales it becomes irreversible, resulting in an "absolute" form of decoherence. The phases can be absorbed as global gauges of the classical fields, so that the wavefunctional becomes a set of gauged classical fields on curved 3d-spaces. By taking into account the density of the distribution of these classical fields, the wavefunctional is fully recovered from them. By counting the 3d-space states according to their densities, the Born rule results. This approach works more naturally without collapse, so background-free quantum gravity seems to lead automatically to a version of the many-worlds interpretation. I will call it the many-spacetimes interpretation. Since the classical states have local beables, they can be seen as ontic, and as supporting different worlds, justifying the derivation of the Born rule from state-counting.
The convergence at the Big-Bang singularity to a homogeneous degenerate 3d-geometry is proposed to explain the time asymmetry of the branching structure in MWI.**Paul Tappenden**

Making sense of Everettian fission without self-location uncertainty

Consider "parallel" measurement processes with multiple possible outcomes, each in a hypothetical stochastic world which is one of an infinite set of hitherto isomorphic stochastic worlds. The set will partition into "branches" whose subset measures are, necessarily, the objective probabilities for each outcome according to stochastic theory. It's possible to view this setup from a novel perspective which makes Everettian fission intelligible. Drop the unnecessary assumption that there's a 1-1 relation between observers and Doppelgänger. A single observer inhabits the set of initially parallel worlds. The observer's body is the set of Doppelgänger. The observer's measurement device is the set of devices, which partitions into subsets which are devices showing different outcomes. The observer fissions when the set of Doppelgänger partitions into cognitively distinct subsets. The objective probabilities of the future outcomes for the observer are the branch measures, so the future occurrence of an outcome does NOT entail that the objective probability of its future occurrence is 1. Trans-temporal identity is resolved via Sider's temporal counterpart theory. Following the Principal Principle, the observer is uncertain as to what will be observed in the sense of assigning multiple partial degrees of belief to the different future observations. Probabilities need not apply only to alternatives.

The talk will consist of clarifying what's in the abstract, based on my papers in Studies 2017 and Synthese 2021. https://arxiv.org/abs/1702.02140,https://arxiv.org/abs/1911.02941

Mordecai Waegell

Unambiguosly Local Quantum Physics in Spacetime

Separability of physical descriptions in presented as the most general definition of locality, without reference to causality. A separable physical description can be broken down into one or more descriptions that make no reference to one another. Most Everettian interpretations are nonlocal by this definition. I present a local many-worlds theory where all physical descriptions of space-like separated events are separable. This theory contains only point objects that move on world-lines in spacetime, carrying local memories along with them which are separable from the memories of any space-like separated object. It thus provides an unambiguous local (many-worlds) hidden variable theory of nature.

David Wallace

The Sky is Blue, and Other Reasons Quantum Theory is Not Underdetermined

I criticize the widely-defended view that the quantum measurement problem is an example of underdetermination of theory by evidence: more specifically, the view that the unmodified, unitary quantum formalism (interpreted following Everett) is empirically indistinguishable from Bohmian Mechanics and from dynamical-collapse theories like the GRW or CSL theories. I argue that there as yet no empirically successful generalization of either theory to interacting quantum field theory and so the apparent underdetermination is broken by a very large class of quantum experiments that require field theory somewhere in their description. The class of quantum experiments reproducible by either is much smaller than is commonly recognized and excludes many of the most iconic successes of quantum mechanics, including the quantitative account of Rayleigh scattering that explains the color of the sky. I respond to various arguments to the contrary in the recent literature.

Poster abstracts

Per Arve
Locality, decoherence and why dBB is actually MWI
TBA

Eyal Buks
Disentanglement and a nonlinear Schrödinger equation
We explore a nonlinear term that can be added to the Schrödinger equation without violating unitarity of the time evolution. We find that the added term suppresses entanglement, without affecting the evolution of any product state. The dynamics generated by the modified Schrödinger equation is explored for the case of a two-spin 1/2 system. We propose an experimental protocol capable of sensing processes of disentanglement.

[1] Eyal Buks, J. Phys. A: Math. Theor. 55, 355303 (2022).

[2] Eyal Buks and Banoj Kumar Nayak, Phys. Rev. B 105, 014421 (2022).

Zuchamo Nsungbemo Ezung
Quantum Probability and the Nature of Reality
The issue of “reality” occupied an important scientific discourse in modern physics especially with that of quantum theory. Quantum theory presents and describes ‘reality’ in terms of particles that are supposedly operating within smallest unit of a known element called ‘atom’. This observable particle is considered to be the basic building block of physical reality. The causal relation between the two or more particles gives shape to reality. Reality in Quantum mechanics is built on the assumption that the causal relation can ultimately determined the position and the momentum of particles which can be certain and accurate. This assumption can therefore take us to the next level our inquiry in understanding ‘reality’. This paper deals

with the systematic analysis about the relationship between the various particles and their behavior at the atomic and sub-atomic level along with their position and momentum, and explores the possibility of applying confirmation in examining quantum theory as a theory of reality. Such an analysis bases itself upon facts of existence and its picturing by statements about reality.

David Oaknin

The Bell theorem revisited: geometric phases in gauge theories

The Bell theorem stands as an insuperable roadblock in the path to a very desired intuitive solution to the EPR paradox and, hence, it lies at the core of the current lack of a clear interpretation of the quantum formalism. The theorem states through an experimentally testable inequality that the predictions of quantum mechanics for the Bell polarization states of two entangled particles cannot be reproduced by any statistical model of hidden variables that shares certain intuitive features. In this paper, however, we show that the proof of the Bell theorem involves a subtle, though crucial, assumption that is not required by fundamental physical principles and, hence, it is not necessarily fulfilled in the experimental setup that tests the inequality.

Vicent Picó-Pérez

Intrinsic Properties in Bohmian Mechanics and MW Theories

The contemporary debate about scientific realism is often framed in terms of notions such as 'intrinsic properties' that are used in different ways. I will seek a definition of intrinsicality that help us to explore the existence of intrinsic properties in fundamental physical theories such as quantum mechanics. According to the primitive ontology approach, a theory cannot be formulated devoid of metaphysical commitments. Besides, the non-primitive ontology can be read off from the formalism of the theory. In both the Bohmian and the Many-Worlds interpretations of quantum mechanics, the primitive ontology consists of particles in space-time and the non-primitive properties are masses, potentials and the wave-function. It is argued that the mass is an intrinsic property of the particles.

Mark Rubin

Preclusion as the Explanation of Everettian Probability

We argue that all those aspects of physical phenomena that we deem probabilistic may be explained by adding to Everett quantum theory “hard” preclusion, the rule that events with a quantum weight below a certain threshold do not occur. Using the Heisenberg-picture Everett ontology, preclusion directly explains the non-occurrence of “maverick” events, in particular macroscopic violations of the second law of thermodynamics. We present a proof-of-concept model that preclusion, in addition, can account for biological evolution in the absence of the existence of objective probability. Since there exists extensive experimental evidence that subjective judgements of probability are to some extent innate, a product of biological evolution, preclusion may thus as well provide a (subjectivist) explanation of probability for those (“non-maverick”) events that are not precluded. The account of probability provided by preclusion is explicit and non-circular, and explains an “empirical Principal Principle,” the observation that subjective judgements of probability are often well-matched to objective probabilities from physical theory.

**Everettian Fission with Particle Trajectories \ **Paul Tappenden
TBA

Carlotta Versmold, Florian Huber, Jan Dziewior, Elina Köster, Jasmin Meinecke and Harald Weinfurter
Paths through the double slit
Bohmian mechanics, a hidden-variable interpretation of quantum mechanics, ascribes reality to the positions and momenta of quantum particles at the cost of a non-local ontology.
Thus, contrary to standard quantum mechanics it explains the double slit scenario with definite particle trajectories, while being fully compatible with the standard theory in all empirical predictions. Nevertheless, the plausibility of the Bohmian picture has been called into question with a version of a double slit Gedankenexperiment by Englert et al. in which the result of a which-path measurement seems to contradict the Bohmian description.
Here, the experimental realization of this Gedankenexperiment is presented. The conditions for the occurrence of so-called "surrealistic" trajectories are realized by using a pair of entangled photons, where one of the photons is sent into an optical double slit interferometer. The average trajectories are recorded using a method inspired by weak measurements.
The description provided by Bohmian Mechanics is then contrasted with a description provided by the Many-Worlds-Interpretation, which, using the weak trace approach, gives an alternative account about the path of the particle in the double slit.