Physics, time and qualia

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Abstract

We suggest that four of the deepest problems in science are closely related and may share a common resolution. These are 1) the foundational problems in quantum theory, 2) the problem of quantum gravity, 3) the role of qualia and conscious awareness in nature, 4) the nature of time. We begin by proposing an answer to the question of what a quantum event is: an event is a process in which an aspect of the world which has been indefinite becomes definite. We build from this an architecture of the world in which qualia are real and consequential and time is active, fundamental and irreversible.

`This formulation makes it clear that the uncertainty relation does not refer to the past."
(Heisenberg, 1949)

1) Introduction

The core of Galileo's new science was the idea that all motion could be represented mathematically while all change could be rendered as motion. To make this credible not only was part of the world discarded but memory of it erased. Sensations, colors and thoughts were not part of the mathematical universe and that came to be thought of as the only universe there was. This splitting of the world had many implications for our understanding of the world itself. Philip Goff's book Galileo's Error: Foundations for a new science of consciousness (Goff, 2019) is focused on one of those implications which is our understanding of qualia and consciousness. But there is another set of implications which is not discussed as often which is the understanding of time.

The aim of this paper is to show how Galileo's original error made possible an even more serious error, this one having to do with our understanding of time. Furthermore, the two issues - the place of qualia in a physical universe and the nature of time - influence each other. The hard problem of consciousness is a very different problem depending on one's conception of time. Tied up in this confluence of questions there are two more: the problems in the foundations of quantum mechanics and the problem of quantum gravity. To us, all four issues: the nature of time, the place of qualia in a physical universe, the foundational problems of quantum mechanics and quantum gravity are all tangled up. They have a common solution. The solutions we adopt to each of them alter the way we understand the others.

2) The hard problem of time

Galileo's error in removing qualities, sensations and awareness from the world, leaving only a universe of quantities and of quantifiable relationships, led to an equally profound error about the nature of time. From the first to the second error is only a few steps. The success of the science of motion led to the hypothesis that the motions and forces of the world - from atoms up to stars - were a system that was causally closed, as all explanations of motion pointed to more motion.

Meanwhile, the success of the "universal laws" posited by Newton made it plausible that all of the motions could be described in mathematical terms - that is in terms of mathematical figures, such as parabolas and hyperbolas, that were quickly found to be solutions to equations that expressed a few simple principles. The achievements of this straightforward methodology were and are stunning. It begins to seem as if nature is intrinsically "mathematical". This can be expressed by hypothesizing that there is a mathematical object, *O*, perhaps a solution to a final, unified set of equations which is a mirror of the history of the universe, *U*. This means that for every property, P of U, there is a theorem *T*, about *O*, and vice versa. We can call this *the mathematical universe hypothesis (Tegmark, 2014).* Making sense of this is harder than it looks, and indeed has not so far been achieved. It is to say the least, unclear to us that the full explanation of many of the processes and structures we observe in the world can be made solely by means of mathematical deduction from the laws of physics.

There are several distinct challenges to the success of the mathematical universe hypothesis. Functional explanations, which we will discuss below, seem necessary to explain many facts about biological and ecological systems (Cortes et al, 2021a,b&c). Many of us argue that there is no algorithm that predicts all functions of a physical system. One biological system that resists our efforts to reduce to physics are brains, we certainly know enough to be confident we don't know how brains they bring forth minds. On top of which it remains plausible that quantum physics is genuinely indefinite. Nor should we ever forget the problem of the initial conditions, which seem both improbable and inexplicable (Penrose, 1978).

The hypothesis of a mathematical universe may seem an innocent bit of physicalism, but it has astounding consequences (Mangebiera - Unger and Smolin, 2014), (Smolin, 2015). It implies that every causal influence, observed to play out in time, can be mirrored by a theorem, which is a timeless truth. A complete mathematical correspondence in all cases reduces laws to theorems concerning the properties of an imagined mathematical object that represents the history of the universe. By doing so, it reduces causation to timeless truths. If everything that will happen in future time can be shown necessary, by a time-less logical argument, then the activity of time is reduced to a computation. So the crime went much deeper than Galileo's expulsion of sensation and qualities from the world, for the chain of implications leads to a conception of a static world, because where logic timelessly reigns, bright colors and sweet music may be the first illusions, but the last illusion certainly must be time itself.

We can make the argument from the other side, where it takes the form of a direct refutation of the claim that there could exist a mathematical object, *O*, which is a mirror of nature, in the sense we described above. The claim is refuted by showing the existence of properties of our world that no mathematical object could explain or describe, let alone mirror. Here is one: in the real world it is always some present moment, which is one of a continual becoming of present moments (Mangebiera -Unger and Smolin (2018), Smolin (2015).

Mathematical logic is genuinely timeless – there is no system in mathematics which allows the possibility of theorems whose truth value depended on whether the subject was irreducibly to our past, present or future. The key word is irreducibly, i.e. the truth value cannot be translated without loss of meaning to replace the tensed words past, present and future with relations to relative clock readings. Or, to put it in Mctaggart's sense: while temporal relations in nature are A-series, mathematics can only express B-series relations (Mctaggart, 1927).

The second kind of fact about the world that cannot be expressed or explained by mathematical truths are those about qualia such as what it's like to see blue. Or what is the unforgettable sound of a B minor seventh chord played on a Gibson SG made before 1960.

3) Quantum mechanics with an active time

We don't often emphasize the centrality of the tensed distinction between past, present and future in the measurement theory of quantum mechanics, but it is there – as indeed Heisenberg, Schrodinger, Dyson and others discussed (Heisenberg,1949), Schrodinger,?? Dyson,).

Physics as developed so far is about the past. All the measurements we analyze were taken in the past. They are compared with the predictions of theories made in the past. Some physicists like to talk about being B-theorists but the actual practice of science is purely A-series. It is easy to see that the A-series structure of past, present and future is baked into the organization of science. The testing of theories by experiment relies on it, as the following argument shows. Let us look at a simple example. A scientific description of a subsystem, say the solar system, begins by taking records of a series of runs of the system. Each run is defined by initial conditions, with respect to some approximately fixed frame, and we follow and record the resulting trajectory, always relative to the frame of reference, until the experiment ends. This means that the actual context for comparing the results of an experiment with a theory is that the experiment necessarily happened in the past of the analysis. This is important because the prediction of the theory will have been some kind of mathematical object - say a trajectory in some space of motions with respect to external idealized elements. What it is compared to is not the system itself, but records of past relative positions. These records are also mathematical objects. What we do when we test the theory is to compare two mathematical objects to each other: the one being records of the past, which is compared to the second, which is a mathematical model of the past. When we compare two mathematical objects, time is not involved because you can check your work at any future time. This is trivially true if what are being compared are timeless records from the past with timeless logical deduction. But it is fallacious when the derivation is compared to actual nature unfolding, becoming in time (Mangabeira-Unger and Smolin,2016).

3.1) Active time versus passive time

We can call the B-series measures of time that figures in records of past motions *weak time*, or passive time. It plays no generative role, it is just used to label and then order records of the past. In (Smolin & Verde, 2021) we define an active conception of time as the process that resolves indefinite circumstances to definite. We call the version of time we champion *resolving time*. It is what Bergson called *creative time (Bergson,??)*. The world is literally remade over and over again, event by event, by the work of active time. By contrast, the "time" that theorists talk about being emergent is not directly related to the resolving time we were just discussing. That passive weak time is not an aspect of the universe at all. It is a mathematical coordinate that we assign to our records of experiments, which by definition is a mathematical object that was created when the runs of the experiment were made it in the past.

We are not dealing here with a conflict between two different definitions of a "time coordinate." We are dealing with two very different conceptions of what a universe is. A time created universe is constructed by the repeated actions of a function that creates novel events, out of the material of present events - which then become past events, or more simply part of the past, which exists only in records that give testimony to what they did in their present moment. According to (Smolin&Verde, 2021) an event is an action which resolves an indefiniteness or ambiguity in the world - which step by step - creates our world. What then exists, moment by moment is a network of these actions of resolution, whose connections are nothing less and nothing more than causation. That is why we see ourselves to be part of a definite world - because all that exists are these movements of resolution. An event is a process, each of which does its job of resolution, then vanishes as it creates a few of the next generation. Then, its work being done, it is gone. A time created world is not a four dimensional manifold, it is a continually recreated, roughly three dimensional network of processes.

4) The Problem of Mental Causation

From a physicalist point of view it is very puzzling that there is consciousness at all. Since physicalists assume that the complete explanation of the behavior of an animal will be found in a full reduction to the underlying laws satisfied by the elementary particles that constitute it, any additional properties would be inessential[1]. But the knowledge argument (Jackson, 1982) demonstrates that what it's like to see blue is exactly such a property.

This of course depends on the laws of physics being deterministic so that a complete specification of the initial state yields a unique final state. Since the laws of physics acting on the initial state already completely determine the future state, seems to be nothing left for qualia to do, no role for them to play in causing behaviour. Qualia are rendered 'epiphenomenal', properties that have no causal impact on the physical universe. Even if they exist in a weak sense of a Russell inspired panpsychism (Russell, 1927)-, in which they represent other aspects of matter, not involved in the dynamical laws – perhaps essential or internal aspects of being – so long as they play no role in dynamics, it can't matter one whit whether they are there or not.

This would then imply that qualia are completely irrelevant for everything an animal

[1] We area grateful to Sean Carroll for a remark on this issue that changed our minds.

may or may not do. The outcomes will be what will be - qualia or none.

But then, why are there qualia? If being a zombie would be every bit as good for our evolution, living and thriving -- why does nature go to such an extent, just to give us a show?

At this point we have a clear choice. We can continue to insist on the divisions Galileo and Newton made, and study only those aspects and subsystems of the universe that lend themselves to mathematical description, within which we hypothesize causal closure. Or we can bring some of those other parts and aspects of the world back into the universe, and search for causal closure within this larger set. It is neither anti-reductionist nor anti-scientific to take this second route.

We have already learned in biology, ecology, medicine etc. how reductionist and functional styles of explanation work together (Cortes et al., 2021a,b&c) to give what David Deutsch calls the "best explanation" (Deutsch, 2011). Once we have a design for a world in which qualia and conscious events may have causal effectiveness in the physical universe, we work like biologists and pose functional questions about how the different parts of our world work together.

We propose a hypothesis.

There will be a mixed functionalist and reductive explanation for why humans and other animals experience qualia (or just experience).

In simple physical systems, many successful explanations are completely reductive, in the sense of relying only on the fundamental laws and initial conditions. But there are cases where the arguments based on reduction alone fail. In many of these cases the right explanation has a functional component. For example let us ask why a particular molecule, hemoglobin, is present in the biosphere in large quantities. Part of the answer is that the molecule is stable under the laws of physics, and those laws are seen to act in multiple settings during which hemoglobin is made.

It is pretty well understood how functional properties play an essential role in explaining the behavior and constitution of living creatures. There are many questions, for example about the very sparse distribution of actual proteins in the space of physically allowed proteins that are explained partly by satisfaction of the laws of physics, but also by what functions the proteins do for the living creatures that create them.

But an essential part of the answer is that hemoglobin is a protein which performs a crucial function for a large number of creatures - namely spreading oxygen through the blood. Because of this, animals that produced hemoglobin had greater fitness and were selected for. But as those creatures thrived so did the proteins that contributed to their fitness.

4.1) Does consciousness serve a function?

Among all the aspects of an animal or human being that contribute to its fitness, few make a greater contribution than consciousness. There is much evidence that the focus of a person's consciousness can be trained and that a trained attention underlies the skills of an athlete, a musician or a hunter. It seems possible, if not likely, that consciousness or awareness had and has a lot to do with the thriving of our species.

It is then very natural to suppose that if the existence of consciousness is to be explicable for a physicalist, it must perform some function that increases the fitness of the creature that is endowed with it. But this requires that consciousness can intervene in the network of causes in the physical universe. But when we try to develop this idea we run immediately into a very strong argument that the physicalists have to their credit, based on the causal completeness of the of the standard Newtonian paradigm.

We are at an impasse. To proceed we must give up the founding idea of the physical sciences, which is the universal governance of nature by a handful of physical principles, expressed mathematically by a causally closed set of equations.

However, we do not want to give up universality altogether, just enough to allow new physical phenomena associated with qualia to play a role in the complete circle of causes. Our theory is framed in an events ontology, and hence we treat some events differently.

To proceed, we accept the implausibility of qualia being anything other than epiphenomenal within the currently understood physical laws and empirically known phenomena. There remains only the hope that innovations in physics may be more hospitable to consciousness: this seems to be the only road if we are to have an embedding of qualia into physics.

We introduce a new regime of physics that is related to qualia in a way that allows qualia to be consequential. We will speak of this as Mode II physics, as opposed to the well understood Mode I.

This is far from a new strategy; it has been followed by most of the attempts to understand the role of awareness within quantum physics. Most of the approaches to quantum foundations do split the laws into two parts, the first being described by unitary Schrodinger evolution in a fixed Hilbert space, which we identify with Mode I.

In most formulations, quantum mechanics is more than this. Collapse of the wavefunction, whether spontaneous or based on a law of some kind, is strictly Mode II.

Indeed in any approach to a completion of quantum mechanics, from Bohr to Bohm, there is a part of the dynamics besides the unitary time evolution. This is where the Mode II physics is to be found. In all these cases, Mode I deals with evolution in Hilbert space, which yields generally indefinite states, given any basis relevant to the macroscopic world. In quantum theory, Mode II deals with everything else, including how definite states are produced. Mode II is also where Born's rule for probabilities, or whatever replaces it is found.

We would like then to propose that:

Mode II is where we will find the physical correlates of consciousness.

Some of the reasons to suppose this include:

- Mode II is where indefinite states are made definite. But consciousness is always definite.

- All past proposals to connect quantum mechanics to consciousness, from Wigner (Wigner and Margenau, 1967,) to Penrose (Penrose,1978), and Chalmers and McQueen (Chalmers and McQueen,2014), invoke a version of Mode II as the site of that connection.

The next question to be posed is whether consciousness and qualia are correlated with all Mode II events. Or are such correspondences rare, so that to be in correspondence with qualia requires further special circumstances.

4.3 Evolving laws and unprecedented events.

We will not comment on the large literature that debates the plausibility of a general panpsychism. We propose that the general implausibility of attributing awareness to every last rock and molecule is avoided when qualia are associated with very special events, or clusters of events.

Part of our overall motivation is to situate the hard problem of consciousness within a theory of a time-made universe. This makes the overall argument for the reality of time at the core of our new conception of qualia. A key part of those general arguments (Pierce,1893), (Smolin,1992), (Smolin, 1997)(Alexander et al 2021) is to establish that the laws must evolve. In particular we argue in (Cortes and Smolin, 2014,2015) that it is hard to square an active time that constructs the universe's history by events, each of which resolves something indefinite, with the Newtonian paradigm, based on unchanging laws. The conclusion of this line of argument is a claim that there are certain events whose causal future cannot be deduced from a complete knowledge of its causal past.

Actually, we can say something quite a bit stronger. *There can be no completely precedented events.* Leibniz's Principle of the Identity of the Indiscernible mandates that there can be no two events in the history of the universe with identical causal pasts and causal futures. Suppose we have two events whose causal pasts are identical. Then Leibniz's principle mandates that their causal futures must be different. Such a world cannot be governed by a deterministic theory, as that would require that if the pasts are identical, then so must be the futures. Even if the futures are different in each case, the statistical distribution of outcomes may be fixed over time.

We must then make a distinction between events which generate a constant statistical distribution of outcomes, whose causal future is at least on a statistical level, a consequence of their causal past, and those which are not governed by any evolution law, deterministic or stochastic. We will call the first kind, precedented or habitual events; the latter unprecedented or "free" events.

This distinction emerges naturally in several theories in which laws are allowed to evolve. One type of theory where the distinction emerges naturally is those governed by the Principle of Precedent.

4.4) The Principle of Precedent

- The **Principle of Precedent** (Smolin, 2005) is an idea about the origin of laws, or rather how the notion of dynamical law could be replaced by a simpler hypothesis.

  It has an especially clear presentation in an operational formulation of quantum mechanics, such as (Hardy, 2001). Each quantum process is broken up into three stages: i) a preparation, by which the experimenter picks out an initial state at an initial time, ii) a unitary evolution generated over an elapsed time T by a Hermitian hamiltonian, U(T), and iii) a measurement made at final time, where the system ends up in one of a number of output states. Given a set of possible input and output states, the experimenter measures the probabilities for each of the input states to become one of the output states:

  p(output, input)

  They arrive at this table of numbers by doing the experiment many times, with different choices of the input states. The theorists see their challenge as having a theory that can predict thee probabilities.

A very important property of these probabilities is that they do not depend on the starting or ending time of the experiments. These probabilities for the different possible outcomes depend only on the elapsed time, T, and not on the initial time, so that the probabilities measured in the next year will converge with those measured over the last 100 years. Given this we could posit a precedence law:

Law of precedence**. Given a preparation for a physical system, chose the output state randomly from the set of past precedents.**

The routine states are those that have a large number of precedents. The novel states are those without precedents.

In the case of a preparation that has many precedents the principle just stated does reproduce an evolution that matches that of quantum theory with a fixed Hamiltonian.

How does the universe choose the outcomes of preparations which have no or few precedents? We propose that *the novel states or events are the physical correlates of conscious events.* At these moments, the universe has perhaps some degree of freedom to choose what happens next. It is these moments of freedom which make up conscious experience.

Those unprecedented moments are presumably common near the universe's origin, and spread throughout the universe. As the universe ages, it takes a higher degree of complexity for a state to be unprecedented. But we can wonder whether complex biomolecules might serve as a reservoir of novel states. Might the biosphere and the brain have evolved, to make use of the special properties of novel states, including the freedom present at those moments to choose a small part of the future. It is not difficult to see that this access to novel states might give an animal a selective advantage.

Note that large molecules are made up of smaller subsystem, such as atoms.
The component atoms will not be novel. What we want to suggest is that if there are entangled or coherent states which are made of many atoms which are sufficiently large and complex to be without precedent, these may serve as novel states.

The freedom in choosing the unitary evolution operator acting on such states will not impinge on the microscopic local dynamics governing each routine component, it will have to act non-locally, on the whole molecule, and be sufficiently weak so as to not have been discovered. Such a term might, for example, favour one folding of a protein over others.

5) Can the definiteness of qualia arise in an indefinite physics?

In the time-created world we propose, the qualia have to be properties of the events, or their causal relations. The creation of an event is a process of resolving an ambiguous or indefinite situation. We claim qualia are associated with the outputs of these processes, which makes it natural that qualia are always definite.

A structural realist, who is a realist about qualia, would attempt to bridge the gaps between sensation and motion opened by Galileo's error by looking for structural parallels between the organization of qualia and the organization of their physical and neurological counterparts.

We have to distinguish those aspects of the structure of qualia which are explained by organization imposed by the brain. An example of these is that

- The moments of awareness seem to define a thick present. There is also a duration of each experienced moment in time of about .5 of a second. Experiments show that the order of two sounds heard within that interval may not be faithfully reproduced. There is also a delay effect.
- We experience qualia, never singly, but bundled together with others in a way that identifies and explains. "Oh, that is an injured red bird, you can see it in the way it holds its wing." These identifications and explanations seem to require the resources of a brain to organize.
- The brain constantly tries to give sense to sensory inputs, resulting in a coherent meaning. Neuroscientists tell us that there is a struggle within the brain to filter from all the senses what should be paid attention to, i.e. which should be part of each moments bundle of conscious perceptions. But almost all the time, the brain resolves the signal in order to avoid giving us ambiguity.
- Similar mechanisms appear to resolve contradiction between our present experience and the memory of past experiences. This resonance between the experience and the memory of the past experiences gives sense to our now. This is also why we see patterns.

There is much to learn about the structures imposed on perceptions which we may use to peer into those neurological systems. But we believe that it may be possible to look past these and search for evidence of those aspects of conscious experience that might be due to the fundamental nature of the world. The latter aspects we may call the irreducible structural aspects of experience.

Here is a short and preliminary list of those:

- Qualia are always definite. We never experience at different times a state, a contrary state, and then their superposition.

- Normally we have at most one conscious experience at a time per person.

- Qualia and conscious moments seem to express the structure of an event in an active time construction of the universe. They turn on and enter the stream of consciousness as soon as they are noticed; they sharpen and resolve something and then are gone. While they are present they are a heterodox mix of modalities and sensations.

- There are no pure qualia, in isolation. Each conscious experience seems to be a complex perception consisting of an array of colours, sounds, sensations of touch and smell, all bound together. They seem at times to be organized around directions going outwards from us, as if there is a phenomenal sphere surrounding each of us on which the colours and other sensations are projected. We will refer to the bundled qualia and thoughts as *moments of awareness*.

- We are conscious of novelties, while unconscious of habitual patterns.

- Our experience seems to provide a background, on which a focus brings some connected qualia in high definition. While you are reading this sentence your focus is on the text, and you have only a dim awareness of the birds singing outside your window. But at their mention your attention is captured by the bird song, then an old memory of a friend who worked on bird songs, and then.

This is clearly just a start – no, actually a rehearsal for a start. There is much to be done to develop the program we have just outlined to discover or construct physics-hospitable qualia. More about this is in ().

6) Causal closure with qualia.

We close by returning to the themes of our first paper, now extended to incorporate the role of awareness and qualia in the construction of a time-created universe:

This is a phenomenology of present events. Nothing exists or persists, things only happen.

The universe is indefinite and under-determined. What we mean by becoming or "to happen" is for *something indefinite to become definite*. This is what we call an event.

The quantities that become definite at an event are called the view of the event. The views are real.

The causal future of some events is determined by their causal past; we say these are precedented. Others, not determined by their past, are unprecedented.

Unprecedented events must choose their next steps. We experience this creativity as awareness.

The universe often surprises itself. Qualia are expressions of the universe to surprise. Pleasure are expressions of acceptance of the surprise.

The quantities that become definite at any event are its endowments, which are passed to each from preceding events and become definite on reception. These endowments include energy and momentum. Each event is brought to happen by the passage of the endowments, from their immediate predecessors to them. These instances of passing on, define the causal relations, which are definite.

The direction from indefinite to definite gives the universe an arrow of time.

The indefinite is also called the future. This is because being indefinite it can at any time become definite - in an event which is definite and real. If it does, it may influence the present moments to come.

The quantum state is nothing but an expression of what we can best forecast or bet about the future, taking fully into account both what is indefinite and definite at this present moment.

The world recreates itself in every moment, as indefinites flash into momentary definites, after which they are nothing. Everything we see around us exists or did just exist, but was gone in the blink of an eye.

Consciousness is connected with - in fact, created by - the resolution of indefinite states. This ties qualia tightly to quantum theory – especially when that is looked at with the perspective of a world created by an active time. This implies a heightened sensitivity to novelties. The ability to detect novelty is not a peripheral or optional feature of the mind/brain-it is its main function. Qualia, we conjecture are signals of the recognition of novel situations. We and other creatures have evolved the ability to do so through evolution - as a creature that can resolve ambiguities quickly will, all things being equal, survive better.

By integrating qualia into the history of fundamental physics, we may have resolved the problem of causal closure. Qualia, as part of the history of fundamental physics, play a role in the causal evolution of the universe.

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