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0. Introduction

The conceptual and technical difficulties involved in creating a quantum theory of gravity have led some physicists to question, and even in some cases to deny, the reality of time. More surprisingly, this denial has found a sympathetic audience among certain philosophers of physics. What should we make of these wild ideas? Does it even make sense to deny the reality of time? In fact physical science has been chipping away at common sense aspects of time ever since its inception. Section 1 offers a brief survey of the demolition process. Section 2 distinguishes a tempered from an extremely radical form that a denial of time might take, and argues that extreme radicalism is empirically self-refuting. Section 3 begins an investigation of the prospects for tempered radicalism in a timeless theory of quantum gravity.

1. How Physics Bears on the Reality of Time

Let me begin with a quotation:

> Time by itself does not exist. Time gets its meaning from the objects: from the fact that events are in the past, or that they are here now, or they will follow in the future. It is not possible that anybody may measure time by itself; it may only be measured by looking at the motion of the objects, or at their peaceful quiet.

This quote is from Lucretius's *De Rerum Natura*. It illustrates the fact that, for a long time now, there have been philosophers who have doubted the reality of time. But if that is indeed a fact, then it seems such doubts must have been misplaced after all! Does that mean it is simply incoherent to doubt the reality of time? I think not. But it does mean that anyone expressing such doubts has three tasks. The first task is to make clear just what *feature* of time it is whose reality is questionable. The second task is to show how we can get along with a concept of time that lacks that feature. The third task is to explain how we mistakenly came to believe in a time with that feature.

Take Lucretius as an example. He is not denying the existence of events, of temporal relations between them such as simultaneity, earlier and later, of a distinction between past, present and future, of change, or of motion. He may not even be denying the existence of temporal congruence relations—that a definite interval of time elapses between events. Perhaps he is merely claiming that we have only two ways of *measuring* the duration of such an interval. We can correlate its beginning and end with events in some more or less regular motion, treated as a clock; or we can simply estimate its duration by reference to our own internal 'sense of time'. At most then, Lucretius is denying the existence of moments of time distinct from events that occur at them, and of an absolute temporal metric, independent of actual physical or mental 'clocks' suited to measure it. To make good his denial, he must show how we can describe and explain our observations and experiences if there are really no such temporal structures. And he owes us an account of how we came to be fooled into believing in them.

Newton described the concept of time he was to employ in his physics in his famous Scholium to the *Principia*. This was richer in structure than that of Lucretius, incorporating not only an absolute temporal metric, but apparently also an ontology of temporal moments, existing independently of any events that may or may not occur at them. Newton even endorsed the common sense idea that time *flows*. But though this idea may well have had significant heuristic value for him in developing the mathematical framework in which to construct his theories (the calculus), it plays no essential role in the final structure of those theories. The great predictive and explanatory success of Newtonian physics seemed to establish the reality of the other features of Newton's time. In retrospect this proved a high water mark for the reality of time in physics from which it has been receding ever since.

In the nineteenth century, Boltzmann's attempts to find a mechanical basis for the physical irreversibility inherent in the second 'law' of thermodynamics highlighted the temporal reversibility of Newtonian mechanics, and indeed of all then known fundamental physical laws. This seemed to show that the distinction between earlier and later was accidental rather than a matter of fundamental physical law. Whether this is so remains controversial to this day. But even if there are temporally asymmetric fundamental physical laws, it is unclear to what extent these can account for the pervasive temporal asymmetries we observe in physical processes. Boltzmann went further, speculating that the manifest asymmetry between past and future was not itself a fundamental feature of time, but rather a reflection of the contingent asymmetries in physical processes, at least in our region of the universe. The idea is that in so far as these processes underlie the operation of our mental as well as physical lives, it is ultimately this feature of our physical situation that accounts for the perceived difference between past and future, which is not, therefore, a real feature of time itself.

Early in the 20th century, Einstein's theories of relativity undermined other features of common sense as well as Newtonian time. It came to be recognized that the temporal interval between noncoincident events is not an invariant quantity, but depends on the state of uniform motion to which one refers those events. If the events happen in such a way that a material particle could travel from one to the other, then the time interval between them is relative to the trajectory of such a particle: in that sense, time intervals are only locally defined. If the events are space-like separated, so not even light (in a vacuum) could travel from one to the other, then even their time *order* must be relativized to a state of uniform motion: this is the famous relativity of simultaneity. Accepting it means acknowledging that for space-like separated events simultaneity, earlier and later are not two place but three place relations, between a pair of events and a state of motion. This presents serious problems for any conception of time according to which a single present moment separates the past from the future, since the Minkowski space-time of special relativity (unlike that of Newton) does not in itself determine which distant events are to count as present.

At least Minkowski space-time permits one (somewhat arbitrarily) to define a global present moment—most naturally as a hyperplane of simultaneity in some chosen frame. But the space-time associated with a generic mass-energy distribution in general relativity will contain no such hyperplanes, and may not even contain a single global 'time-slice' (a space-like hypersurface with no boundary). As is well known, Kurt Gödel found a novel solution to the field equations of general relativity with no global time-slice and used its existence as a premise to mount a controversial argument for the unreality of time. He argued that time is unreal in so far as there can be no objective lapse of (global) time in Gödel space-time. But we have strong evidence that the space-time of our universe differs from Gödel space-time precisely in the crucial respect that it does indeed possess a global foliation into time-slices. This not only allows for the possibility of an objective lapse of global time in our universe.

It also seems to guarantee that our universe changes, and indeed expands, as time passes. For we have strong evidence that the spatial geometry and matter distribution of our universe differ in just this way on each time-slice, no matter how these slices are defined!

However, there is a very different view of how general relativity treats time. Adopting this alternative view would void any guarantee of a changing universe, and replace it with the radical denial that there is any real physical change in a universe described by general relativity. The alternative view has been advocated not just by some physicists but also recently by the philosopher John Earman (forthcoming). At first glance, it may seem merely perverse to recommend that we adopt an alternative interpretation of general relativity with such radical implications for the nature of time and change. But such an interpretation can seem quite natural, or even inevitable, from a certain perspective.

This perspective emerges from attempts to create a quantum theory of gravity by applying standard quantization techniques to general relativity. Such attempts have been beset for forty years or more by severe conceptual as well as technical problems, including the notorious 'problem of time in quantum gravity'. Here is one way of stating that problem. Because of the vanishing of the Hamiltonian, the quantum gravity analog to the Schrödinger equation (the Wheeler-DeWitt Equation) implies that the wave-function(al) that supposedly describes the evolution of space and its contents never changes! This problem then comes back to haunt classical general relativity. For the basic strategy behind many attempts to quantize that theory has been to begin with a constrained Hamiltonian formulation, in which the theory is taken to describe the dynamics of space and its contents, rather than as corresponding to a collection of models of matter distributions in space-time. But in such a formulation, it seems that the genuine physical quantities of classical general relativity are all constants of the 'motion'—their values do not change! This raises two fascinating philosophical questions: Why do we experience change in such a Parmenidean universe?' and 'Is it even coherent to suppose that an *experience* of change might be an *illusion*?' I want to come back to these questions after completing this initial survey of ways in which physical theorizing bears on the purported reality of time.

As I have explained, relativity threatens the reality of various features of Newtonian and common-sense time such as the absoluteness of simultaneity and of temporal ordering of all events, the absoluteness of temporal duration, and the existence of a unique global division of events into past, present and future.

Quantum mechanics, on the other hand, seems quite conservative in its attitude toward time. Both non-relativistic quantum mechanics and relativistic quantum field theories simply assume some fixed space-time background—be it that of Newton, Minkowski or a curved general relativistic space-time. Such conservatism has even been thought to go over into a positively reactionary attitude toward time. I shall give three examples.

All fundamental theories known to Boltzmann were time-symmetric in this sense: If the models of the theory contained a motion from state S_1 at time t_1 to state S_2 at time t_2, then they also contained a 'time-reversed' motion from $S^T{}_2$ at time t_1 to $S^T{}_1$ at time t_2, where S^T indicates the so-called time-reversed state corresponding to state S (e.g. S^T might be a state of a bunch of Newtonian particles in which these particles have the same positions but oppositely directed momenta to what they have in state S). While requiring a slightly more subtle notion of time-reversal, relativity theory did not affect this general feature of physical theories. But with quantum mechanics the situation is more complicated. The time-dependent Schrödinger equation is the fundamental dynamical equation of non-relativistic quantum mechanics. It has been taken to be time-reversal invariant, but this is true only if one requires the time-reverse of the wave-function describing the state of a system to be given by taking its complex conjugate as well as replacing t by $-t$. This may he justified by claiming that the empirical content of the theory is exhausted by transition probabilities from one state to another, and the suggested requirements ensure that these are time-reversal invariant. But this claim is controversial. Moreover, the quantum measurement process seems to introduce a fundamentally time-asymmetric element into the theory through the notorious 'collapse of the wave-packet'. Craig Callender (2000), for one, has argued that a thorough analysis of quantum mechanics reveals that it is *not* a time-reversal invariant theory. If that's right, then the theory reintroduces the distinction between earlier and later into physical theory at a fundamental level.

Naive versions of the collapse postulate in quantum mechanics take it to occur at an instant, even though prior to collapse the wave had significant amplitude over a wide region. Any such physical process could he instantaneous in only one frame. If all collapses occur instantaneously in a single frame, then the collapse postulate picks out a preferred frame as a matter of physical law, in violation of the principle of relativity. Such violation could be extremely hard to demonstrate experimentally because of decoherence effects, and so cannot be taken to be in conflict with existing evidence supporting the principle of relativity. The existence of such a preferred frame would motivate an argument for additional temporal structure in Minkowski space-time (or a general relativistic space-time) corresponding to an absolute quasi-Newtonian time over and above the relativistic times appropriate to (relativistic) reference frames in various states of motion in that space-time. The presence of such structure could be taken to reinstate absolute simultaneity and a global distinction between the past, present and future of an event. Similar conclusions may be drawn from a Bohmian account of violation of Bell inequalities, involving information travelling from one wing of an Aspect-type apparatus to the other at an arbitrarily fast speed in some unique, privileged reference frame—a frame that is experimentally undetectable, thus preserving the principle of relativity at an empirical level. Maudlin (1994), for one, seriously entertains such an account.

As a third and final example of an attempt to draw a reactionary conclusion about the real features of time from quantum mechanics, consider John Lucas's recent appeal to quantum mechanics to locate the flow of time at a fundamental level in physical theory. I quote:

> There is a worldwide tide of actualization—collapse into eigenness—constituting a preferred foliation by hyperplanes (not necessarily flat) of co-presentness sweeping through the universe—a tide which determines an absolute present ... Quantum mechanics ... not only insists on the arrow being kept in time, but distinguishes a present as the boundary between an alterable future and an unalterable past. (Butterfield, ed. (1999), p. 10)

Lucas believes that real quantum-mechanical collapse reinstates not only absolute simultaneity, but also real tense, i.e. an objective but constantly changing distinction between past, present and future corresponding to the objective passage of events from potentiality to actuality (or nonactuality). If he's right, then quantum physics has finally come up with the cash to back Newton's promissory note in his reference to the flow of time!

But this was counterfeit coinage concealed in the metaphysician's sleeve. Even if quantum mechanical 'collapse into eigenness' were to occur on a global time-slice this would require at most an absolute time in the sense of a privileged foliation by such slices. The fact that the state on a slice is not determined by those on earlier slices in no way precludes the actual determinateness of states at all time(-slice)s. An opponent who denies the metaphysical reality of tense could even point to a sense in which 'collapse into eigenness' renders the past more open than the future. For while a state may collapse into any one of a discrete set of eigenstates of the measured observable, such a post-collapse eigenstate is compatible with each of a continuous infinity of non-orthogonal pre-collapse states!

Quantum mechanics is a distraction from the battle over the reality of tense, which is more properly fought on metaphysical ground. Radical deniers of tense such as Mellor (1981) would argue that Lucas's 'worldwide tide of actualization' falls prey to McTaggart's (1908) notorious argument for the unreality of time. For the kind of change Lucas takes quantum mechanics to underwrite—an event's changing from potential to actual (or counterfactual) with the passage of time—is an example of what Mellor called 'McTaggart change'. The radical response to Lucas is to agree with McTaggart that the idea of such change is simply incoherent, though fortunately not required for things to undergo the less metaphysically loaded kind of change we, as well as quantum physicists, suppose them to.

If I'm right, then quantum mechanics alone neither establishes nor poses any threat to the reality of time. But things change (if anything does!) when one tries to come up with a quantum theory of gravity. It turns out to be very hard to fit even *ordinary* change into the resulting framework of thought. And some (notably Julian Barbour) have given up the attempt and simply declared that change, motion, indeed time itself are all ultimately illusory.

2. The Perils of Parmenides

Before plunging into the details of canonical quantum gravity and the constrained Hamiltonian approach to general relativity as a gauge theory, I want to step back to survey the ground that needs to be covered by anyone who wishes to use these details to argue for the unreality of time, or at least of change.

Here is the basic situation. Any theory of gravity, quantum or classical, is a physical theory. We have no reason to believe this, or any other physical theory, without evidence. The evidence for any physical theory is empirical: it consists, ultimately, in the results of observations and experiments. Whatever physical form these take, they must give rise to experiences in scientists who perform them if they are to serve their epistemic purpose. Such experiences will be events—at least mental if not also physical. For there to be such events, it must be possible to make sense of the idea that they occur in time—that the *earlier* mental state of an observer was a state of ignorance, while his or her *later* mental state was a state of knowledge (at least in a weak sense of that term). Moreover, at least in the typical case, a physical theory is confirmed by testing its *predictions*—statements made *at an earlier time* in ignorance of their truth-value and then checked by making observations *at a later time*. Both the formulation of a prediction and the performance of a subsequent observation to test it are *acts*—events of a particular kind involving different intentional states that the observer is in at different times. It follows that the testing of a prediction presupposes the possibility of *change*—in the mental state of an observer, if not also in the physical state of the world that he or she is observing.

All these points are blindingly obvious. But note what follows from them. There can be no reason whatever to accept any theory of gravity—quantum or classical—which entails that there can be no observers, or that observers can have no experiences, some occurring later than others, or that there can be no change in the mental states of observers, or that observers cannot perform different acts at different times. It follows that there can be no reason to accept any theory of gravity—quantum or classical—which entails that there is no time, or that there is no change. Now it is important to note that it does not follow that no such theory can be *true*. But any such theory would have the peculiar feature that, if true, there could be no reason to accept it. To borrow a term from Jeff Barrett (1999), any such theory would be *empirically incoherent*. It follows that no argument that concludes that time, or at least change, is unreal, and which starts from the assumption that some theory of gravity—quantum or classical—is true, can have any empirical basis. In the case of a quantum theory of gravity, this negative conclusion may not come as a surprise. Not only do we not currently have any convincing quantum theory of gravity, but the prospects for finding evidence to support any such theory are at best distant. But classical general relativity is a different matter: we take ourselves to have considerable evidence supporting this theory, especially following careful analysis of the binary pulsar studied by Hulse and Taylor. But if general relativity, correctly interpreted, implies the nonexistence of time, or of change, then we must be wrong to take this evidence to support the theory after all. For the correct interpretation of this supposed evidence must undercut its epistemic credentials. Put bluntly, a radically timeless interpretation of general relativity entails the impossibility of performing any of the experiments and observations, the performance of which we ordinarily take to provide our reasons to believe that theory. Such an interpretation makes the theory empirically self-refuting.

Now I want to suggest that things may not he entirely hopeless for a contemporary Parmenidean. His strategy must he to embark on an ambitious reconstruction project—the project of coming up with serviceable replacements for those temporal concepts—implicit as well as explicit—which, as currently understood, presuppose the existence of time and change at a fundamental level. A glance at the history of science reveals a number of similar reconstruction projects necessitated by advances in fundamental physics, some more radical than others. As has often been noted, these have typically involved the 'demotion' of some concept, formerly assumed to pick out some fundamental element of physical reality, to something more anthropocentric. The up/down distinction and the distinction between motion and rest both came to be relativized to particular states, and so to be naturally associated with the perspective of an observer in such a state. With relativity, the same thing happened to spatial and temporal intervals, and also to energy and momentum. So-called secondary qualities like colours and sounds came to be regarded not as fundamental properties of objects and events, but rather as corresponding to a humanly convenient way of categorizing those things in response to fundamental properties such as the wavelengths of light and sound that they reflect or emit. There is a tradition of describing such conceptual displacements in radical terms. Galileo famously contributed to this tradition when he said in *The Assayer*

> I think, therefore that these tastes, odours, colours, etc. so far as their objective existence is concerned, are nothing but mere names for something which resides exclusively in our sensitive body, so that if the perceiving creatures were removed, all of these qualities would be annihilated and abolished from existence. But just because we have given special names to these qualities, different from the names we have given to the primary and real properties, we are tempted into believing that the former really and truly exist as well as the latter.

I place contemporary Parmenideans in the same radical tradition as Galileo. Detecting the need for a conceptual shift in our temporal concepts in the light of contemporary physics, they characterize that shift in eliminativist terms. Noting the consequent failure of our standard temporal vocabulary to mark out any fundamental temporal facts, they take our assertions employing this vocabulary to be massively in error. They take the view that the denial of time and/or change is merely the honest acknowledgment of this error.

But even with regard to secondary qualities like colours and sounds this radical approach is not the only way to go, and it may not be the best way. Even if we acknowledge that the colour of an apple is not among its most fundamental physical attributes, distinguishing Red Delicious from Granny Smiths by colour is extremely convenient given the contingencies of human colour vision and ambient lighting conditions. There continue to be good reasons for deploying colour concepts which allow that Red Delicious apples are red even when the lights are out, and would continue to be red even 'if the perceiving creatures were removed'. A less radical response to a scientifically induced conceptual shift is desirable for practical purposes, and in this case it is certainly available. We know it is available because we successfully avail ourselves of it on a daily basis. But this transcendental argument from practice conceals an important scientific and philosophical question: 'How is the human practice of making what we call colour discriminations possible if colour is not a fundamental property of physical objects?' Any account of colour that denies that colour is a fundamental property of physical objects owes us at least a sketch of an answer to this question. And any such account that entails that the question is unanswerable is *ipso facto* unacceptable.

Physical science has had the resources to provide such a sketch since the seventeenth century. The details have been significantly modified as the account has become more sophisticated since Newton's classic investigations on the nature of light and colours. But the sketch is still broadly as follows. We see a red apple when ambient light is reflected from its surface to our eye. The surface of the apple has intrinsic physical properties (describable without mentioning colour) that dispose it preferentially to reflect certain components of the ambient light incident on it while absorbing others. The reflected light therefore has a different composition than the ambient light: again, this composition is describable in physical terms without mentioning colour. Light with this different composition is disposed to elicit a characteristic sensation when it enters the open eye of a human with normally functioning visual and neural systems. An English speaker experiencing this sensation has acquired the ability to apply the term 'red' to objects like apples that elicit it in normal viewing circumstances, along with other discriminatory and inferential abilities associated with his or her possession of the corresponding concept. Thus while a fundamental physical account—of apples, the light they reflect, and the human who sees them—need include no mention of colour, it does not follow that apples have no colour. Rather, that account explains our abilities successfully to deploy colour concepts like *red* in ordinary circumstances, and thereby legitimizes this application. It licenses the claim that Red Delicious apples really are red, even though redness is not a fundamental physical property.

The central claim of a contemporary Parmenidean is that time, or something basic that presupposes time (such as change), is in effect a secondary quality. The claim is that, like colour, time and/or change is not a fundamental feature of the world. And just as Galileo went on to deny the objective existence of the secondary quality of colour, so too a contemporary radical Parmenidean denies the objective existence of time and/or change. But while agreeing with Galileo about the importance of the primary/secondary quality distinction, the philosopher Locke may be read rather as drawing a distinction between two kinds of objective properties. On this reading, the primary qualities of an object are those that figure in a fundamental (corpuscularian) account of its nature: the secondary qualities arise from complex arrangements of matter in particular circumstances that dispose it to affect our senses in certain characteristic ways. This suggests a moderate, neo-Lockean, alternative to the radical contemporary Parmenidean who simply denies the reality of time and/or change. It is to accept that time and/or change is a secondary quality, but to go on to explain how it arises from some more fundamental features of the world in particular circumstances that explain both why we experience our world as temporal and why we are warranted in so describing it. I think the contemporary Parmenidean would be wise to take this suggestion seriously. Only in this way can he or she rescue the physical theory that supposedly grounds Parmenideanism from empirical incoherence.

A claim that time or change is a secondary quality requires some initial clarification if it is to seem defensible. What is time or change supposed to be a secondary quality *of*? This question reads such claims too literally: what matters is being secondary, not being a quality. One may explicate the claim that time is a secondary quality as follows. Qualitative and quantitative temporal relations such as being earlier than or occurring two weeks after are to be understood not as external relations but as relations that hold, when they do, by virtue of intrinsic properties of objects including their relata. Barbour calls these objects 'Nows': a Now is something like an instantaneous global state of the universe in relative configuration space. The intrinsic properties of Nows may be compared, and if all the Nows have the right kinds of intrinsic properties, then it will follow that certain events bear one another relations corresponding to qualitative and quantitative temporal relations such as being earlier than or occurring two weeks after. The claim then is that when such temporal relations obtain between a pair of events, they do so only by virtue of the nontemporal properties of all the Nows. This is a deeply Leibnizean picture, in which neither time nor temporal relations are literally qualities, even though both arise from what may be considered primary qualities of Nows.

A second difficulty is presented by the inclusion of *state of motion* in lists of primary qualities, beginning with Locke. For motion clearly requires change. Indeed, Aristotle took any kind of change in the properties of a substance to be a sort of motion, taking what we call motion to correspond merely to change of place, or local motion. But if motion is a primary quality, then change cannot be a secondary quality, and nor can the time it presupposes.

This difficulty does not present a serious challenge to the thesis that time and change are secondary qualities. To resolve it, it suffices to note that the set of primary qualities should not be taken to be defined by any fixed list. What should appear on a list of primary qualities at any stage in the development of science are just those properties and relations that science then takes to be fundamental. Thus a list of the primary qualities of elementary particles today would include such things as electric charge and intrinsic spin. Indeed contemporary physicists have playfully added what they call 'colour' and 'flavour' to their list of primary qualities of quarks, confident that after Galileo and Newton no-one could confuse these with the colour and flavour of Red Delicious apples! Physics long ago abandoned the corpuscularian restriction of primary qualities to those observable or 'conceivable' (i.e. imaginable) in ordinary middle-sized objects.

The fact that motion is historically taken to be a primary rather than a secondary quality does not refute the view that time and/or change is a secondary quality.

I hope these considerations have at least made conceptual space for claims to the effect that change and the time it presupposes are secondary qualities. But so far we have seen no reason why reflection on contemporary physics should motivate anyone to try to occupy that space.

3. The Timelessness of Canonical Quantum Gravity

In the canonical quantization approach to a quantum theory of gravity pioneered by Dirac, one begins with a formulation of general relativity as a constrained Hamiltonian system, and proceeds to quantize the theory by following a standard prescription that works well when applied to other theories like electromagnetism. If one starts with the usual variables (rather than Ashtekar's new variables), then one ends up with the Wheeler-Dewitt equation. The equation itself is very complex, and may not even be well-defined mathematically. I know of no realistic solutions to the full equation (though Smolin (2001), p. 40 claims to have found some), but approximate solutions have been found to simplified versions of the equation at least in restricted circumstances (e.g. by Hawking and Hartle). What would a solution look like? It would be a complex-valued function whose arguments are 3-dimensional spatial geometries with matter fields defined on them. Hartle and Hawking call a cosmological solution a 'wave-function of the universe'. If this is indeed analogous to an ordinary quantum mechanical wave-function, then the square of its absolute value should associate a probability to each value of its arguments. But this raises two related problems. It is unclear what these are probabilities of: and whatever they are probabilities of, those probabilities don't change with time since there simply is no time parameter in the equation (it is like a 'time-dependent' Schrödinger equation with a zero Hamiltonian operator). One might expect a solution to the equation to yield answers to questions like 'What is the probability of finding the system with such-and-such matter fields and spatial geometry if these were measured at time *t*?' But since the equation itself contains no time parameter, any answer to such a question can only be independent of the value of *t*. This would make sense if the state of the system in fact never changed with time. One kind of Parmenidean takes this to warrant the denial of change at a fundamental level in any system described by the Wheeler-Dewitt equation: I shall call this character a *changeless Parmenidean*. But there is an even more radical Parmenidean who concludes not merely that any system described by the Wheeler-Dewitt equation is in fact devoid of change, but rather that the absence of any time parameter in the equation shows that there is in fact no such thing as time. The idea is that, rather than having the same answer for all values of *t*, a question of the form 'What is the probability of finding the system with such-and-such matter fields and spatial geometry if these were measured at time *t*?' has a false presupposition—that there are times to which '*t*' may refer! I shall call this even more extreme Parmenidean a *timeless Parmenidean*. Both Parmenideans are now committed to the kind of reconstruction project I outlined in the previous section.

I now want to focus on the Parmenidean views of two physicists: Carlo Rovelli and Julian Barbour. I am indebted to John Earman (forthcoming) for his exposition of Rovelli's views, as well as to Rovelli (1991). I take Barbour's book *The End of Time* and his (1994a,b) as my source for his views. Rovelli's idea of 'evolving constants' may suggest that he is a changeless Parmenidean—denying change but not time, while it is natural to take Barbour to be a timeless Parmenidean. But in the end I think they are both timeless Parmenideans, though Barbour's Parmenideanism is still the more radical.

In a constrained Hamiltonian formulation of dynamical theory, it is normal procedure to require that genuine physical quantities be gauge invariant, i.e. that they commute with all the (first-class) constraints. This requirement is motivated in part by consideration of examples of theories such as classical electromagnetism in which there are independent reasons to conclude that quantities that are not gauge invariant (such as the electromagnetic potentials) are indeed unobservable, while gauge invariant quantities (such as electromagnetic fields) are observable. In general relativity (or indeed any diffeomorphism-invariant dynamical theory) the requirement of gauge invariance implies that the only genuine quantities are those that commute with the Hamiltonian constraints. But since the Hamiltonian constraints generate the time-evolution of the system, it follows that the only genuine physical quantities in such a theory are constants of the 'motion'! We have a 'frozen' dynamics: no genuine physical quantity changes. This looks like changeless Parmenideanism. Note that this conclusion has been arrived at purely at the *classical* level, even though one main reason to employ the constrained Hamiltonian formulation of a dynamical theory is as a prelude to quantizing that theory.

Rovelli's idea of 'evolving constants' can also be explained at the classical level. The idea is that, for many constrained Hamiltonian systems (including diffeomorphism-invariant ones), there will be some parameter which can be thought of as a 'clock' variable—think, perhaps, of the radius of the expanding universe in a spatially compact model of general relativity. Now this parameter will not itself be gauge invariant, and nor will some other quantity in whose 'evolution' one might be interested (say, a parameter corresponding to the density of matter in that universe). But one can construct a continuous family of gauge invariant quantities corresponding, for example, to 'density of matter-at universe radius *R*', for varying *R*. Now each of these is a genuine physical quantity, and while each individual quantity is constant, the 'evolution' of the universe's matter density may be taken to he reflected in the continuously varying values of these quantities with varying *R*. We have the illusion of change while everything really stays the same!

But how can we explain our experience of change by appeal to such evolving constants? Earman (forthcoming) suggests two ways to go. The first would be simply to postulate some primitive human faculty which lets us interpret the difference between two constant quantities such as 'matter density d_1 at R_1' and 'matter density d_2 at R_2' as an instance of change. The second, and perhaps more promising, would be to show how the physics of the objects and our psychology combine in such a way that we represent the world as filled with change despite the fact that no genuine physical quantity changes. Both these strategies strike me as hopeless. More importantly, I don't think Rovelli himself would be tempted to pursue either strategy. My reason for saying this is that it seems to me that while Rovelli is indeed aware of the need to somehow explain the temporal character of our experience, and in particular our experience of change, he himself does not introduce his evolving constants to that end. His primary concern is to arrive at a quantum theory of gravity by some canonical quantization technique. The evolving constants are introduced not to explain our illusion of change in a changeless world, but to provide a substitute for time in a fundamentally timeless theory. They are there to help us to do fundamental physics, not to explain the temporal character of our experience. How then are we to do that? Here Rovelli appeals to a different tactic. Two quotes are highly relevant

> An accepted interpretation of [the disappearance of the time coordinate from the Wheeler-DeWitt equation] is that *physical* time has to be identified with one of the internal degrees of freedom of the theory itself (*internal time*). (1991, p. 442)
> ... we do not address the problem of the existence of an exact internal time in general relativity. Instead, we assume, first, that a way to obtain an approximate description of the world as we see it (with time) can be extracted from the theory, second, that this description is valid only within the approximation. (p. 443)

As I understand him, he believes that the task of accounting for the temporal character of the world as we experience it is to be undertaken in three stages. The first stage is to develop a coherent (and hopefully empirically successful!) quantum theory of gravity. The second is to apply this to derive the existence of some kind of internal time *as an approximation in a classical limit*. And the final stage is to use this approximate internal time to account for the temporal character of the world as we experience it—since such experiences are inevitably going to occur only under circumstances in which the approximation of the classical limit is valid. Now Rovelli himself says that 'The physical hypothesis that we put forward is the absence of any well-defined concept of time at the fundamental level'. (p. 442) This makes him a timeless Parmenidean in my terminology. It would be consistent with his program to develop a quantum theory of gravity which contained nothing remotely like time, as long as an approximate time could be retrieved from this theory in the classical limit. But (he thinks) it turns out that the best way of aiming for a quantum theory of gravity is to use 'evolving constants' associated with 'clock parameters' as technical substitutes for the fundamental time that is missing from that theory. I can see nothing in the programme that requires these 'evolving constants' to play any role in retrieving an approximate internal time in the classical limit. And it is this latter project which is eventually supposed to make the connection with our temporal experience, not the project in which he is initially engaged in constructing a quantum theory of gravity which will have this limit. Of course, we philosophers await the successful completion of the former project before we can be satisfied that the hoped-for quantum theory of gravity is not merely internally consistent but also empirically successful. For, as I stressed in the previous section, we can have no empirical reason to believe such a theory if it cannot explain even the possibility of our performing observations and experiments capable of providing evidence to support it. And in the absence of convincing evidence for such a theory we have no good reason to deny the existence of time as a fundamental feature of reality.

Barbour explicitly denies the existence of time. Once more, his denial is intimately connected to his attempts to make sense of the Wheeler-DeWitt equation. Unlike Rovelli, he makes no mention of 'evolving constants', but he does make considerable efforts to show how what is, for him, our *illusory* experience of time arises. His basic explanatory device is that of what he calls a 'time-capsule'. This is a highly-structured 'Now'. Recall that for Barbour, Nows of various kinds and multiplicities constitute the basic furniture of the world. To get an idea of what a Now is supposed to be, one is supposed to think initially in temporal terms. In those terms, a Now corresponds to an instantaneous relative configuration of the universe. But of course, Nows are neither instants nor contained in any independently existing time: they just exist atemporally. Most Nows are not time-capsules. But amongst the vast number of Nows are a few whose internal structure contains a representation of an entire sequence of other Nows—a sequence that, when appropriately ordered in accordance with the internal properties of each represented Now, comes to represent what looks like a possible *history*. These are the time-capsules. Barbour's central idea is that experiencing such a time-capsule gives rise to the (misleading) belief that it does indeed represent the sequence of events that have actually occurred, so that the 'history' apparently represented in the time-capsule in fact occurred as a unique sequence of events in time.

A solution to the Wheeler-DeWitt equation assigns probabilities to all Nows, and Barbour conjectures that it must do so in such a way as to enormously favour those that correspond to time-capsules. He offers little support for this conjecture, and this lacuna has been highlighted as the weak link in his argument by Jeremy Butterfield (forthcoming) in his review of Barbour's book. But let's assume that the conjecture turns out to be true. How would this establish Barbour's claim to have accounted for our experiencing a literally timeless world as temporal?

The truth of the conjecture would leave most of the needed reconstruction still to be carried out. The task is to show how, in a fundamentally timeless world composed ultimately only of Nows, it is possible for there to be observers who naturally experience that world as temporal—as having a history and incorporating motion and change. To do this it would be necessary to explain why observers in a timeless world have experiences of particular kinds, including experiences of motion, apparent memories of past events, observations of mutually consistent apparent records of past events, and so on. That is what the high probability of time-capsules is supposed to do. Barbour cannot begin to explain the *character* of our experience until he has first explained how a timeless world can contain *observers* capable of *having experiences* with any character at all. The explanation has to start from the Nows, since Barbour takes everything else to he composed of, or supervenient upon, these. The first step, then, must be to provide a reconstruction of observers in terms of Nows. Ordinarily we think of observers as enduring embodied things that maintain their identities *through time*. If we are wrong to think of observers in this way, how can we think of them?

This is only the first of many basic questions to which Barbour owes us an answer if he is to carry off a successful reconstruction of our temporal experience from timeless elements. We need to be told what it is for an observer to have different experiences at different times without assuming the independent existence of such times. We need to know what it is for a particular Now to be actual rather than merely possible. And we need to understand what the probabilities generated by a solution to a timeless Wheeler-DeWitt equation are probabilities of; and how their concentration on time-capsules helps to account not only for the general character of our temporal experience, but also for those special experiences of scientists capable of confirming the theory of quantum gravity on which the whole reconstruction project rests.

In my judgment Barbour's published works do not provide clear, consistent and satisfactory answers to these questions. But they do contain the materials for a charitable interpretation of his project that might do so. It is in this constructive spirit that I offer the following answers on Barbour's behalf.

Begin with Barbour's 'many-instants' interpretation of quantum theory, and of quantum cosmology in particular. This agrees with Everett that there is no physical wave collapse. Barbour supposes that the solution to a Wheeler-DeWitt equation for our universe assumes a WKB form over a significant region of the whole space of relative configurations, with a semi-classical factor representing its gross features, and a quantum factor associated with the finer details of it structure. He conjectures that the solution's probability density is sharply peaked on time-capsules, each apparently recording in its configuration a history of the development of the gross features of the universe. Moreover, these time-capsules are supposed to be arrayed along what may be called 'streamers' in relative configuration space in such a way that those in any particular streamer cohere with one another, in two senses. Each time-capsule in a streamer itself contains multiple (almost) mutually consistent apparent records of the universe's prior development. And the capsules in a streamer may be ordered in a sequence whose elements apparently record a single history of the gross features of the universe up until successively later stages in its development.

Within this framework we may begin to answer the questions posed earlier. Begin with the modal status of the Nows. The time-capsules in each streamer collectively portray an apparent history of a world, with relatively minor inconsistencies in their individual representations of that history. The time sequence of a history is portrayed by virtue of the nested time-capsules' representations: hence temporal relations are not external relations between real events, but relations between portrayed events determined by internal relations among the time-capsules that portray them. An event counts as actual relative to a streamer just in case it figures in the apparent history the streamer portrays: a Now counts as actual relative to that streamer if and only if it contributes to the portrayal of the apparent history. In both cases actuality is indexical. The apparent histories portrayed in distinct streamers are like David Lewis's possible worlds. No apparent history is any more real than the others. In this sense all possible worlds are equally real (or unreal)! All Nows are real. Since only those Nows within a streamer contribute to a possible world, there is a sense in which only these Nows are possible—the rest are impossible, though still real! A residual vagueness attaches to all these categories, since the sharp peaking of probability that defines the streamers leaves these with 'tails' of low probability. This modal vagueness is ontological rather than conceptual or linguistic, and constitutes a provocative and potentially problematic consequence of the view.

An observer is basically a physical object whose structure permits the formation of internal records in the configurations of its 'memory'. In the case of human observers, some of these internal neurological record states determine the contents of experience and conscious memory. Any enduring physical object is taken to be constituted by, or at least to have its states supervenient upon, appropriate events portrayed by the Nows in a streamer. So now we have our observers, and human observers with experiences. Any human experience is determined by that human's neurological state at a particular Now. A person will have different experiences at different Nows. Some of these will include representations of others, integrated in such a way as to be experienced as having happened earlier. Others will be integrated in such a way as to be experienced as perceived motion.

Streamers 'branch' in global configuration space. This induces branching of the possible worlds they portray and of physical objects, including observers, in such worlds. We suppose that the relative multiplicities of Nows of each type reflect the probabilities derived from a solution to the Wheeler-DeWitt equation. Consider a physicist about to perform a quantum measurement. The physicist and his environment are in a possible world portrayed by a streamer in universal configuration space. Many different streamers branch off from the Now that includes the physicist's experience as he is about to perform the experiment—at least one streamer for every possible measurement outcome. The Wheeler-DeWitt probabilities give the relative numbers of streamers corresponding to each possible outcome. The physicist's experiential state contains no information fixing which of these streamers portrays the 'future history' of him and his environment. But the Wheeler-DeWitt probabilities may be used to condition his expectations, by yielding the probability that the streamer portraying the state he now experiences also portrays this rather than that outcome of his measurement. This finally gives empirical content to the Wheeler-DeWitt probabilities. These do not specify the probability of a particular Now being real, or actualized, or even of its being experienced as actual. Instead, when conditionalized, they yield the probability that an apparent history will continue in one way rather than another. Finally we see how it is that an observer can come to have experiences of a kind capable of confirming the theory of quantum gravity that entails a Wheeler-DeWitt equation which issues in a timeless probability density on the space of global relative configurations. It is striking that experiences whose apparent content so misleads one about the course of history may nevertheless come to provide evidential support for a theory that predicts them. In this respect the view involves a radical reinterpretation of the content of experience in the tradition of Galileo's defence of Copernicanism by reinterpreting our experience of a 'stationary' earth.

This sketch of a Barbourian account of experience is radically incomplete and slurs over problems sufficiently serious to justify extreme scepticism about the feasibility of the whole reconstruction project. It is best to think of it, not as a defence of Barbour's view, but rather as an exploration of conceptual possibilities. As such, it serves as an illustration of the radical moves that may be required before adopting an interpretation of a theory of quantum gravity that demotes time to secondary quality status if one is to avoid rendering that theory empirically incoherent.

Let me summarize my discussion of the prospects for attempts to establish timeless Parmenideanism by reflection on the canonical approach to quantum gravity. Rovelli acknowledges the need for a timeless quantum gravity to explain the temporal character of the world as we experience it, but he has a quite different motivation for introducing his 'evolving constants'. While Barbour portrays himself as a radical timeless Parmenidean, he has made serious efforts to explain what he takes to be our *illusion* that we inhabit a temporal world. But his efforts still fall short of what would be needed to do that. Moreover, a successful explanation of our experience of a temporal world on the basis of a fundamentally timeless theory cannot establish this experience as wholly *illusory*. For our only evidence for such a theory must come from experience of a temporal world.

Now we have no current empirical evidence for any theory of canonical quantum gravity. But we do take ourselves to have considerable evidence supporting *classical* general relativity. This makes it interesting to examine a recent argument by John Earman (forthcoming) in support of an interpretation of classical general relativity according to which there is no change in fundamental physical magnitudes.

As I read him, Earman's argument against change in the general theory of relativity (GTR) comes in two versions. The first begins by noting that GTR is superficially indeterministic in the following sense. A complete specification of the metric and matter fields on and to the past of a time-slice S that is a Cauchy surface fixes the development to the future of S only up to a diffeomorphism d that reduces to the identity on and to the past of S: if $m_1 = < M, g, T >$ is a solution to the field equations, so is $m_2 = < M, d^*g, d^*T >$, where d^* is the drag-along corresponding to the diffeomorphism d. The argument continues by recommending adoption of a suggestion by Bergman (1961) that genuine observables be restricted to diffeomorphism-invariant quantities. Such quantities do not discriminate between m_1 and m_2, which may consequently be regarded as physically equivalent, thereby neutralizing the threat of indeterminism. But this restriction turns out to imply the apparently absurd conclusion that there can be no change in local physical quantities, as long as these are built up from Bergmannian observables.

The obvious response to this argument is to accept the absurdity of its conclusion, and to treat it as a *reductio* of Bergmann's suggested restriction on observables. One can still regard m_1 and m_2 as equivalent representations of a single physical situation if one takes their diffeomorphically related geometric objects (such as d^*g, g) to represent the same physical quantities. From this perspective, the choice of d^*g (say) in m_2 rather than g in m_1 to represent the spacetime metric is fundamentally no different than the choice of one coordinate system rather than another in which to represent the components of g. Both are merely choices among alternative mathematical representations of the same physical reality. In each case, connecting the representation to observation requires coordinating mathematical objects to directly presented physical objects and processes. Different choices simply require different coordinations. The physical determinism of GTR may be secured without adopting Bergmann's suggested restriction on observables.

It is interesting that it was Bergmann who made this suggestion, since he was an influence behind the constrained Hamiltonian formulation of GTR, and it is to this formulation that Earman's second version appeals. The second version advocates a different, though related, restriction on observables. This time, it is maintained that a genuine observable must be gauge invariant, in the sense of commuting with all first-class constraints. Since the Hamiltonian constraints generate motion, it follows that any such observable will be a constant of the motion, again apparently implying that there is no change in any genuine physical quantity. But despite its initial plausibility within the constrained Hamiltonian framework, the new restriction on observables is controversial. In particular, its applicability to the Hamiltonian constraints has been rejected by Kuchar (1992, 1999) and others. And even its initial plausibility depends on adopting the constrained Hamiltonian formulation of GTR—A formulation that is strictly optional prior to quantization, and only one of several frameworks in which physicists have struggled to develop a quantum theory of gravity.

Another argument (not offered by Earman) appeals to the ontology of GTR. Our common sense notion of change requires an object that endures while having different properties at different times. But no such enduring objects are postulated by a field theory like GTR. Hence there can be no common-sense change in a general-relativistic world.

This argument fails also. While GTR does not itself postulate enduring things, neither does it exclude them. In some models of GTR, classical fields are distributed in such a way as to provide just the right kinds of spatio-temporal continuity to connect up what may consequently be regarded as succeeding stages of enduring objects that supervene on them. Moreover, GTR can be taken to underwrite causal links between these stages even though it does not itself make causal claims. In these circumstances, even though GTR by itself does not entail the existence of enduring things, it makes room for their existence. Moreover, changes in the properties of such objects from earlier to later time-slices are naturally taken to supervene on variations in underlying fields. Property change is not only compatible with GTR: GTR nicely accounts for the possibility of property change.

The standard interpretation of classical general relativity as a space-time theory without restrictions on observables does allow for the existence of enduring physical objects like tables, chairs, planets, stars, you and me. Moreover, this interpretation allows for the possibility of change, including those changes in the world and our mental states that we take to ground our reasons for confidence in general relativity. Any interpretation that cannot allow for our possession of this evidence is *ipso facto* inferior, whatever other advantages it may seem to have. I have found wanting two arguments based on alternative interpretations that involve restrictions on what can count as observable. But if such an argument were to succeed it could not rationally convince us to adopt a changeless-Parmenidean interpretation of the theory absent an adequate account of what we take to be the changes that warrant our acceptance of the theory in the first place. If experiments turn out to warrant belief in general relativity only interpreted as an indeterministic theory, then, surprising as it may seem, we should believe that the world is described by an indeterministic general relativity. The only alternative would be to suspend belief in one of our best theories altogether. The role of the philosopher of physics as intellectual conscience of the practicing physicist does not license such a sweeping condemnation.

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