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Chapter 14

Presentism and Quantum Gravity

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Abstract

There is a philosophical tradition of arguing against presentism, the thesis that only presently existing things exist, on the basis of its incompatibility with fundamental physics. I grant that presentism is incompatible with special and general relativity, but argue that presentism is not incompatible with quantum gravity, because there are some theories of quantum gravity that utilize a fixed foliation of spacetime. I reply to various objections to this defense of presentism, and point out a flaw in Gödel's modal argument for the ideality of time. This paper provides an interesting case study of the interplay between physics and philosophy.

1. Introduction

I am a presentist: I believe that only presently existing things exist[1]. Contrast presentism with eternalism: the eternalist believes that past, present, and future things all exist. Assuming that there are three spatial dimensions, the eternalist believes that the universe is four-dimensional, and while there are different events in different regions of this so-called "block universe", the universe as a whole does not change. The presentist, in contrast, believes that the universe is three-dimensional.

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[1] At least, I am a presentist on Mondays, Wednesdays, and Fridays — those are the days I am writing this paper.

I am also a Heraclitean: I believe that change is a fundamental aspect of reality. Contrast Heracliteanism with Parmenideanism: the Parmenidean believes that fundamentally, there is no change. It is possible to be a Parmenidean presentist, where the universe simply consists of three dimensions of space, and the state of the things in that space does not change with time. (Julian Barbour (1999), for example, can be construed as holding this position.) From now on, by "presentism" I mean Heraclitean presentism.

The point of this paper is not to argue for presentism, but to defend presentism from a particular type of argument that is often taken to refute it[2]. The form of the argument is as follows:

(1) Presentism is incompatible with relativity theory (usually the focus is on special relativity).
(2) Relativity theory is our most fundamental theory of physics[3].
(3) Presentism is incompatible with our most fundamental theory of physics (from (1) and (2)).
(4) Presentism is false (from (3)).

W.V.O. Quine provides a good example of this argumentative tradition:

> Just as forward and backward are distinguishable only relative to an orientation, so, according to Einstein's relativity principle, space and time are distinguishable only relative to a velocity. This discovery leaves no reasonable alternative to treating time as spacelike. (Quine, 1960, p. 36)

If we have discovered that time is spacelike, then we have discovered that presentism is false, since, just as we do not ontologically privilege events *here* in space as the only events that exist, so we cannot privilege events *now* in time as the only events that exist.

Perhaps the most famous version of the argument sketched above is given by Hilary Putnam. Relying on special relativity, Putnam gives an argument with

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[2] Nor is a point of this paper to make clear the difference between presentism and eternalism. Some philosophers (such as Callender, 2000, p. S588) claim not to see the difference, and there is nothing I can briefly say (beyond what I said above) to convince them otherwise.

[3] For those who believe there is no such thing as "our most fundamental theory of physics", (2) can be replaced with

> (2*) There is no theory of physics more fundamental than relativity theory,
> and similarly (3) can be replaced with
> (3*) Presentism is incompatible with a theory of physics *T*, which is maximally fundamental; that is, no theory more fundamental than *T* exists.

This allows that, while one theory can sometimes be declared more fundamental than another, there is no one most fundamental theory (following, e.g., Belot, 2000).

the following conclusion:

> the problem of the reality and the determinateness of future events is now solved. Moreover, it is solved by physics and not by philosophy. We have learned that we live in a four-dimensional and not a three-dimensional world .... (Putnam, 1967, p. 247)

If we live in a four-dimensional world, presentism is false.

The reader will no doubt recognize that the move from (3) to (4) is non-trivial; whether or not one sanctions it depends on to what extent one believes that our best scientific theories give truths about the nature of reality. Debates about this issue have been going on for quite a while now, and the proponents of the various positions are rather entrenched; it would be preferable if the presentist could reject the argument without having to reject scientific realism. My approach to rejecting the argument starts with the relatively uncontroversial claim that (2) is false: general relativity is incompatible with quantum mechanics, so our most fundamental physics can be found in the nascent theories of quantum gravity, which attempt to resolve the incompatibility. It turns out that there are some theories of quantum gravity, which are compatible with presentism. Thus, (3) is false, and presentism is unrefuted.

2. Fixed foliation quantum gravity

There are currently two main approaches to developing a theory of quantum gravity: the particle physics approach, leading to string theory and M theory, and the general relativity approach, leading to canonical quantum gravity and loop quantum gravity. (For a review of the various approaches, see, e.g., Rovelli, 1998.) Canonical quantum gravity faces the much-discussed problem of time: on the standard way of quantizing general relativity, the fundamental dynamical equation does not include a time parameter (see, e.g., Isham, 1993; Kuchar, 1999). One proposed solution to the problem of time is first to specify a foliation: that is, a particular way of dividing up spacetime into spacelike hypersurfaces. In the most-discussed version of this solution, the spacetime is foliated into CMC hypersurfaces — that is, hypersurfaces of constant mean (extrinsic) curvature (Beig, 1994; Fischer & Moncrief, 1997). Then, the theory is quantized, resulting in a fundamental dynamical equation that can describe the evolution of a system over time.

This CMC theory of canonical quantum gravity is not the only version of fixed foliation quantum gravity. Within canonical quantum gravity, there are other ways of fixing the foliation besides relying on CMC; a version of Bohmian quantum gravity has a fixed foliation (Goldstein & Teufel, 2001, p. 284); and there are more radical approaches as well (such as the general ether theory of Schmelzer, 2001).

Fixed foliation quantum gravity is compatible with presentism. To show this, it will be helpful to utilize the semantic view of scientific theories (see, e.g., van Fraassen, 1987). A scientific theory is taken to have two parts, the *theoretical structure* and the *theoretical hypotheses.* The theoretical structure consists of a family of mathematical models. For standard spacetime theories, each model of the theory can be taken to consist (at least in part) of an ordered set, whose members are a four-dimensional manifold and various geometric objects giving the spacetime structure of the manifold. The theoretical hypotheses are propositions expressing how the mathematical models should be taken to represent the world, according to the theory (see, e.g., Giere, 1988, p. 80).

The theories of fixed foliation quantum gravity are spacetime theories, in that the theoretical structure of the theory is such that the models of the theory are four-dimensional spacetime models. This does not mean that fixed foliation quantum gravity entails eternalism, though. To see what the theories say about the world, one must look to their theoretical hypotheses. One could have an eternalist theoretical hypothesis that specifies that the events in the spacetime model all represent existing events, so that past, present, and future events all exist. One could, however, have a presentist theoretical hypothesis that specifies that a particular spacelike hypersurface in the foliation represents the set of existing events, and that the set of existing events changes with time.

In practice, the physicists who put forth theories of fixed foliation quantum gravity do not specify what metaphysics of time their theory entails. This means that the theory simply leaves open that metaphysical issue; the openness can only be resolved with an interpretation[4]. The reason why theories of fixed foliation quantum gravity are compatible with presentism, then, is that they can be interpreted in such a way that they entail presentism.

3. Presentism and relativity theory

It is worth making explicit why I give the defence of presentism at the level of quantum gravity. If presentism was compatible with special and general relativity, but incompatible with quantum gravity, (3) would nevertheless be true — presentism would still be incompatible with our most fundamental theory of

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[4] For simplicity, I am speaking as if there is a definite line between theory and interpretation, but in fact I agree with van Fraassen's point:

> The division between the theory proper and the interpretative elements already introduced by its main or earliest proponents is of course to some extent arbitrary. ... it would be unrealistic not to see the official theory as to some extent indefinite. (van Fraassen, 1994, p. 7)

physics. Because of this, the compatibility of presentism with special and general relativity is *prima facie* irrelevant to the issue of the truth of presentism[5]. I will argue that this *prima facie* appearance is in fact correct.

Despite the *prima facie* irrelevance, much has been written on the issue of the compatibility of presentism with special and general relativity. The general sentiment among philosophers, which I share, is that presentism is incompatible with special and general relativity. (This general sentiment is expressed by, e.g., Savitt, 2000; Callender, 2000; Saunders, 2000; for dissensions, see Hinchliff, 2000; and Craig, 2000, 2001.) The reason for the general sentiment is that the models of special relativity have spacetimes of the form $<M, n>$, and the models of general relativity have spacetimes of the form $<M, g>$, where M is a four-dimensional manifold, n a Minkowski metric, and g a generalization of the Minkowski metric; these spacetimes do not have a foliation into spacelike hypersurfaces as part of their structure. Granted, such a foliation can sometimes be added to the spacetime: for some models of general relativity, for example, the spacetime structure itself allows one to pick out a foliation, such as the CMC foliation mentioned above (see Isenberg, 1995, for details)[6]. But the point

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[5] Many presentists seem unaware of this. For example, Mark Hinchliff (1996) is a presentist, and he expresses concern regarding the compatibility of presentism and special relativity. He considers the possibility of rejecting the special theory of relativity, but writes:

> The special theory is one of our best-confirmed scientific theories of the nature of time. (Hinchliff, 1996, p. 131)

This claim is false; the special theory is a decisively refuted theory of the nature of time. Special relativity is incompatible with such phenomena as the gravitational redshift and gravitational lensing, phenomena that provide evidence for general relativity. (See, e.g., Misner, Thorne, & Wheeler, 1973, pp. 177–191.)

Because Hinchliff thinks that special relativity is a well-confirmed theory, he suggests that presentism needs to be modified to make it compatible with special relativity. Hinchliff mentions various proposed modifications, but seems most sympathetic to relativized presentism, where what is present is relative to a frame of reference. The problem with both relativized presentism and all the other ways of modifying presentism to make it compatible with special relativity is that the modified presentism turns out to be an *ad hoc* and unbelievable doctrine.

[6] John Norton (2000, p. 42) points out that locally (in "mini-spacetime") all spacetimes of general relativity are Minkowskian and respect the relativity of simultaneity, but "Once we relate these mini-spacetimes to the larger spacetime, the richer structure of the larger spacetime may select a preferred simultaneity relation". Moreover, this preferred simultaneity relation "can be projected into the mini-spacetime". This puts in context Steven Savitt's (2000, pp. S572–S573) point that "every general relativistic model (M, g) is required locally to have the structure of Minkowski spacetime".

is that the foliation is not a part of the spacetime structure as given, and thus imposing such a foliation amounts to changing the theory[7].

That is simply a brief explanation of the general sentiment that presentism is incompatible with special and general relativity; it is not the point of this paper to defend that sentiment. Supposing that sentiment is correct, why would one think that it has relevance for the truth of presentism?

One possible answer is that, in the absence of a definite theory of quantum gravity, one would expect results about the nature of time in relativity theory to carry over to quantum gravity. The problem with this answer is simply that there are various extant theories of quantum gravity, and in some of them — such as the theories of fixed foliation quantum gravity — this expectation is not borne out.

This reply leads to another possible answer: instead of just *expecting* the incompatibility of presentism with relativity theory to carry over to quantum gravity, one should *require* that it does so. This view is widely held (at least implicitly) by physicists working on quantum gravity. For example, Carlo Rovelli writes:

> special relativity teaches us something about time which many of us have difficulty accepting ... there is no physical meaning in the idea of 'the state of the world right now' .... (Rovelli, 2001, p. 111)

Addressing theories such as fixed foliation quantum gravity, Rovelli says:

> Many approaches to quantum gravity go out of their way to reinsert in the theory what [general relativity] teaches us to abandon: a preferred time. ... At the fundamental level we should, simply, forget time. (Rovelli, 2001, p. 114)

In the course of a scientific revolution, scientists do not completely reject old theories and old ways of thinking. Copernicus, for example, attempted to hold on to Aristotelian physics while espousing his revolutionary heliocentric cosmology. Similarly, it is not surprising that physicists draw certain lessons from relativity theory, which they utilize in formulating theories of quantum gravity. Moreover, as has often been pointed out, one of the interesting aspects of the development of quantum gravity so far is that the theories are not being generated subject to the constraint of new experimental data. Physicist C. J. Isham draws this consequence:

> This lack of hard empirical data means that research in the subject has tended to focus on the construction of abstract theoretical schemes that are (i) internally consistent (in a mathematical sense), and (ii) are compatible with some preconceived set of concepts. (Isham, 1994, p. 5)

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[7] It is perhaps worth making this idea more explicit. The idea is that the theory of general relativity implicitly includes the claim that *all it takes* to specify the structure of a general relativistic spacetime is the specification of the manifold M and the metric g. Since imposing a foliation is adding more to the structure of spacetime than the manifold and the metric, imposing a foliation amounts to changing the theory of general relativity.

He also says:

> In practice, most research in quantum gravity has been based on various *prima facie* views about what the theory *should* look like — these being grounded partly on the philosophical prejudices of the researcher involved .... (Isham, 1997, p. 169; cf. Butterfield & Isham, 2001, p. 38)

While Isham does not explicitly give examples of preconceived sets of concepts or philosophical prejudices, presumably he has in mind ideas such as the ones presented above: there is no physical meaning in 'the state of the world right now'; at the fundamental level we should forget time.

The lesson I draw from this is that, in spite of the fact that many physicists believe that relativity theory teaches us that a good theory is incompatible with presentism, there is no compelling reason for presentists to agree. Because of the lack of data to back up the claim that a good theory is incompatible with presentism, and because of the existence of potentially viable theories of fixed foliation quantum gravity, the presentist can simply maintain that the physicists are drawing the wrong lessons from relativity theory.

Moreover, there is historical precedent for physicists drawing a wrong lesson from a particular theory, with the mistake only realized once a more fundamental theory is thoroughly developed. For example, according to the traditional way of understanding electromagnetism, the vector potential is not real, while the electric and magnetic fields are. The advent of quantum mechanics, with its successful prediction of the Aharonov–Bohm effect, suggests that the vector potential is real as well[8].

I conclude that all the literature on the issue of whether presentism is compatible with special or general relativity is, while perhaps intrinsically interesting, irrelevant to the issue of whether presentism is true. Even if presentism is incompatible with special and general relativity, it in no way follows that presentism is incompatible with our most fundamental physics.

4. Belot and Earman's objection

I know of just two passages in the philosophy literature which are directly relevant to my defense of presentism on the basis of quantum gravity. Both passages can be construed as giving objections to my argument. I will consider

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[8] Belot (1998, p. 532) takes the approach that "until the discovery of the Aharonov–Bohm effect, we misunderstood what electromagnetism was telling us about our world". Another approach, though, is to say that the Aharonov–Bohm effect shows another way in which electromagnetism is false. This should not be viewed as a deep philosophical issue: what the approaches disagree about is the referent of "electromagnetism". (I grant, though, that which approach one takes may influence how one goes about developing more fundamental theories.)

Gordon Belot and John Earman's objection in this section and Craig Callender's in the next.

Belot and Earman (2001) base their discussion on the following passage from physicist Karel Kuchar:

> foliation fixing prevents one from asking what would happen if one attempted to measure the gravitational degrees of freedom on an arbitrary hypersurface. Such a solution ... amounts to conceding that one can quantize gravity only by giving up general relativity: to say that quantum gravity makes sense only when one fixes the foliation is essentially the same as saying that quantum gravity makes sense only in one coordinate system. (Kuchar, 1992, p. 228)

While Belot and Earman do not address Kuchar's first criticism, it is worth replying to. Kuchar is presumably being metaphorical: there is no part of the theory, which implies that one cannot *ask* what would happen if one attempted to perform a particular measurement. I take it that Kuchar is saying either that according to the theory the physical process of engaging in such a measurement is physically impossible, or that the theory makes no predictions for the outcome of such a measurement. If the former, then the theory makes an interesting empirically testable prediction about whether it is possible to perform such a measurement, and it would be best to test the prediction before drawing any conclusions about the theory. I think, though, that Kuchar is making the latter claim, that the theory is incomplete because it does not make predictions for certain physically possible measurements. But this latter claim is unjustified. In Newtonian physics, for example, there is a preferred foliation, and yet one could use the theory to make a prediction for the measurement of the gravitational field on an arbitrary hypersurface, by using the theory to make predictions for the outcomes of measurements at various spacetime locations on the hypersurface. Kuchar has given no reason that one could not do the same sort of thing in fixed foliation quantum gravity.

Belot and Earman comment only on the last part of the Kuchar quote:

> This criticism is extremely telling. To forsake the conventional reading of general covariance as ruling out the existence of preferred co-ordinate systems is to abandon one of the central tenets of modern physics. Unsurprisingly, [fixed foliation quantum gravity] has few adherents ... . (Belot & Earman, 2001, p. 241)

Let me be clear: fixed foliation quantum gravity does *not* require a preferred coordinate system. Kuchar does not say that it does: he adds the qualification "essentially", though he does not explain what he means by this. Moreover, Belot and Earman I think agree with my claim that fixed foliation quantum gravity does not require a preferred coordinate system. At the beginning of their article, they say that philosophers

> have all learned that Kretschmann was quite correct to urge against Einstein that the 'General Theory of Relativity' was no such thing, since *any* theory could be cast in a

> generally covariant form, and hence that the general covariance of general relativity could not have any physical content … . (Belot & Earman, 2001, p. 213)

What Belot and Earman go on to argue, though, is that the physical content of the general covariance of general relativity is that the theory *ought* to be formulated in a generally covariant fashion. While Belot and Earman consider different notions of general covariance, they never dispute the claim that any theory can be cast in a generally covariant form, when general covariance is understood as the criterion that there are no preferred coordinate systems. They point out, for example, that one can give a generally covariant formulation of Newtonian mechanics (2001, p. 214). Similarly, one can give a generally covariant formulation of fixed foliation quantum gravity; it follows that such a formulation would not have a preferred coordinate system.

The above discussion leads naturally to the following argument against fixed foliation quantum gravity: its most perspicuous formulation is not generally covariant, and this is a mark against it. This argument has been given by Barbour:

> general covariance is physically vacuous. I believe that the physically significant issue is not whether or not points have a priori individuation, but the relative complexity of rival theories when expressed in generally covariant form. (Barbour, 2001, p. 203)

Here I think the best response for the presentist is to bite the bullet, and admit that fixed foliation theories of quantum gravity in their generally covariant form are more complex than standard theories of quantum gravity in their generally covariant form. The presentist can simply maintain that this particular criterion of simplicity is not a guide to truth.

Before moving on, it is worth pointing out that, in a later paper by Kuchar, he repeats the last portion of the passage from his 1992 paper, with one change:

> foliation fixing … amounts to conceding that one can quantize gravity only by giving up general relativity: to say that quantum gravity makes sense only when one fixes the foliation is essentially the same thing as saying that quantum gravity makes sense only in one reference frame. (Kuchar, 1999, p. 182)

This change from "coordinate system" to "reference frame" is crucial. Focussing on coordinate systems leads to the confusion about general covariance dealt with above. Focussing on reference frames, however, is unproblematic: the proponent of fixed foliation quantum gravity will agree that there is a preferred frame of reference, and can admit that there is a sense in which this is "essentially" the same thing as saying the theory makes sense only in one reference frame.

5. Callender's objection

Craig Callender (2000) also has a discussion that is relevant to my defence of presentism on the basis of quantum gravity. After arguing that tensed theories like presentism are incompatible with special relativity (at least as traditionally formulated), Callender points out that quantum mechanics perhaps gives some reasons to postulate a fixed foliation of spacetime, and mentions fixed foliation quantum gravity. He then writes:

> should the friend of tenses point to these developments in support of tenses, or at least, in support of brushing aside the challenge from special relativity? No. Developments in physics may push us away from the traditional understanding of relativity, but I urge the reader not to allow the tensed theory to do the same. This is not because I believe that only arguments based on physics ought to have a bearing on our interpretations of physics. Good arguments in metaphysics often rightly have some influence on interpretations of physics. The problem is that I simply don't believe that the arguments in metaphysics in favor of tenses are particularly good ones, though this is an argument for another paper. (Callender, 2000, pp. S596–S597)

Callender says that we should not allow a tensed theory such as presentism to push us toward a non-traditional understanding of relativity, because the arguments for presentism are bad ones. But regardless of the strength of the arguments for presentism, the presentist is not required to endorse a non-traditional understanding of relativity. The presentist can simply say that presentism is incompatible with special and general relativity, and hence special and general relativity are false.

Moreover, what Callender says in the above passage does not justify his "No" answer to his initial question. Here is a more precise version of his question: does the existence of fixed foliation quantum gravity give the presentist justification for rejecting the argument against presentism on the basis that presentism is incompatible with special relativity? The point of my paper is to argue for the "yes" answer, and nothing Callender says above casts doubt on that answer.

The passage from Callender continues, though:

> Here I can only ask, if science cannot find the 'becoming frame', what extra-scientific reason is there for positing it? If the answer is our experience of becoming, we are essentially stating that our brains somehow have access to a global feature of the world that no experiment can detect. This is rather spooky. If the answer instead comes from conceptual analysis on metaphysical categories such as change, we must ask whether there is any reason to think that our concept *accurately* mirrors reality. Our concept of (say) change is loaded with pre-scientific connotations. Why think that it reveals something about the properties of spacetime that science cannot? (Callender, 2000, p. S597)

I see no reason that the presentist is committed to the antecedent of the conditional question Callender starts with. The presentist can admit that science has not yet found the 'becoming frame' — that is, the preferred foliation — but the presentist can simply explain that this is because the preferred foliation is a part of a theory of quantum gravity, and there is currently no direct experimental evidence for or against the various theories of quantum gravity. As explained by for example Kuchar (1999, p. 181), the empirical predictions of a fixed foliation theory of canonical quantum gravity will differ depending on *which* foliation is selected as fixed. Thus, assuming that some fixed foliation theory of canonical quantum gravity is true, science can in principle find the becoming frame.

All these conclusions about the nature of theories of quantum gravity are tentative though; suppose that it turns out that Callender is correct to say that science cannot find the becoming frame. I nevertheless find the rest of his argument unconvincing. Consider first those presentists who believe that presentism is true on the basis of our experience of becoming — they hold that, without objective temporal passage, there would not be any experience at all[9]. Callender suggests that these presentists believe that phenomenal experience gives them access to a feature of the world science cannot detect. But what is that feature? Such presentists need not claim that phenomenal experience tells them *which* foliation is the metaphysically privileged one; they can simply say that phenomenal experience demonstrates that there is becoming. Moreover, there is a sense in which they can maintain that all scientific experiments demonstrate this as well: all scientific experiments eventually culminate in a phenomenal experience, such as when an experimenter looks at the record of a measurement apparatus. Since all phenomenal experience involves an experience of becoming, then (according to this sort of presentist) all scientific experiments provide evidence for presentism.

Now consider those presentists who believe that presentism is true on the basis of conceptual analysis. Here I think that Callender's argument is somewhat stronger, if only because arguments on the basis of conceptual analysis are generally more defeasible than arguments on the basis of experience. Again, though, such presentists need not claim that conceptual analysis demonstrates

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[9] I find this presentist doctrine plausible, but I do not really see how to give a good argument for it. The best I can come up with is the following. Consider a three-dimensional block universe, with no time dimension, and no temporal passage. It seems clear that no conscious experience could exist in such a universe. But now imagine adding an extra dimension to that universe, so one has a four-dimensional block universe, with no temporal passage. Adding the extra dimension does not seem to be adequate to produce a universe that allows for conscious experience. Just as the three-dimensional block universe is necessarily devoid of conscious experience, so too is the four-dimensional block universe.

This is obviously not an adequate argument, but I am not aware of any better ones. But just because we do not have a good argument for the presentist doctrine in question does not mean that the doctrine is false. In fact, I think that doctrine is part of the motivation that many philosophers have to be presentists.

which foliation is the metaphysically privileged one; they can simply say that conceptual analysis demonstrates that there is becoming. But Callender can be read as asking: science does not show that there is becoming, so why should we expect conceptual analysis to show that? The presentist can reply as follows. The issue of whether or not there is becoming is a philosophical issue; we should not expect science to determine that issue. All we should expect is that science should not turn out to be *incompatible* with presentism, and thus we should expect the correct theory of quantum gravity to be a fixed foliation theory.

At this point a question naturally arises: what should the presentist do if physicists eventually settle on a theory of quantum gravity, which is incompatible with presentism? There is no simple answer to this question. Different presentists would give different answers, depending on the general issue of how they evaluate the relative strength of physics-based arguments as compared to philosophy-based arguments, and depending on specific issues such as the extent to which they are convinced by the philosophical arguments for presentism, and the extent to which they believe that the final theory of quantum gravity was arrived at by a warrant-inducing process.

6. Gödel's modal argument

Kurt Gödel's (1949) famous modal argument for the ideality of time on the basis of general relativity is implicitly an argument against presentism. There has been a fair amount of discussion recently about Gödel's argument (see, e.g., Savitt, 1994; Earman, 1995; Yourgrau, 1999; Dorato, 2002). If Gödel's argument is viewed as being about the nature of time in spacetimes of general relativity, then I find this recent discussion interesting and illuminating. In this section I will show, however, that Gödel's argument tells us nothing about the nature of time in our universe.

Gödel's argument, very briefly, is as follows. Some spacetimes of general relativity, such as the Gödel universe, cannot be foliated into spacelike hypersurfaces. Thus, in those universes, there cannot be an objective lapse of time; in those universes, presentism is false. Gödel then writes:

> It might, however, be asked: Of what use is it if such conditions prevail in certain *possible* worlds? Does that mean anything for the question interesting us whether in *our* world there exists an objective lapse of time? (Gödel, 1949, pp. 561–562)

Gödel then gives the crucial modal step of his argument:

> if someone asserts that this absolute time is lapsing [in our world], he accepts as a consequence that, whether or not an objective lapse of time exists ... depends on the particular way in which matter and its motion are arranged in the world. This is not a straightforward contradiction; nevertheless, a philosophical view leading to such consequences can hardly be considered as satisfactory. (Gödel, 1949, pp. 562)

With that, his paper ends.

An implicit assumption of Gödel's argument is that the Gödel universe is physically possible (that is, that the laws of our universe are compatible with those of the Gödel universe). This is made clear in various reconstructions of Gödel's argument: Savitt (1994, p. 468) explicitly says that the Gödel universe is "physically possible"; Yourgrau (1999, p. 47) writes that "the actual world is lawlike compossible with the Gödel universe"; and Dorato (2002, p. 8) calls the difference between the Gödel universe and our universe "non-lawlike". Moreover, as far as I can tell, these philosophers believe this thesis of physical possibility. Only Dorato (2002, p. 29) addresses the issue of quantum gravity, in a footnote: "until a reasonably agreed upon quantum theory of gravity is available, we can assume that [general relativity] *is* a fundamental physical theory".

Pace Dorato, I maintain that, if we are trying to discover the nature of time in this universe, it is crucial to consider quantum gravity. Our most fundamental physics suggests that our universe is one where a theory of quantum gravity is true, and general relativity is incompatible with all the main theories of quantum gravity; hence general relativity is in all likelihood false. In all likelihood, then, no spacetime of general relativity is physically possible, and Gödel's assumption that the Gödel universe is physically possible is false.

To see that this assumption is necessary for Gödel's argument to go through, suppose that a theory of fixed foliation quantum gravity is true, and that the theoretical hypotheses of the theory entail that (or the theory can be interpreted in such a way that) an objective lapse of time exists in all models of the theory. Applying Gödel's argument, one who (correctly) says that absolute time is lapsing in our world

> accepts as a consequence that, whether or not an objective lapse of time exists ... depends on the particular way in which matter and its motion are arranged in the world. (Gödel, 1949, p. 562)

But this is manifestly false: according to the hypothetically true theory of fixed foliation quantum gravity, an objective lapse of time exists regardless of how matter and its motion are arranged in the world. In conclusion, Gödel's argument is based on a false assumption about our universe, and thus tells us nothing about the nature of time in our universe.

There is one comment worth making about fixed foliation quantum gravity, inspired by Gödel's modal argument. For at least some versions of fixed foliation quantum gravity, such as the CMC version, which foliation is fixed depends on the distribution of matter in the universe. Belot and Earman (2001, p. 247) point this out, and conclude that "the time which results in this case is certainly not the absolute time of Newton". The presentist can grant this point: Newton wanted time to flow without relation to anything external, while there is a sense in which, in the CMC version of fixed foliation quantum gravity, the flow of time depends on the distribution of matter. But there is no need for the presentist to maintain that the foliation is the same in all physically possible worlds. If there is a foliation in the spacetime model, which represents our world, then presentism can be true in our world, and if there is a foliation in all the spacetime models of the fundamental physical theory of our world, then all versions of Gödel's modal argument are evaded.

7. The future of presentism

Despite this paper's emphasis on fixed foliation quantum gravity, I recognize that it is in no way a popular approach to resolving the incompatibility of quantum mechanics and general relativity. The two most popular approaches, M theory and loop quantum gravity, appear to be incompatible with presentism. Nevertheless, one must be careful: there are two aspects of these theories, which one might think are incompatible with presentism, but which actually are compatible — or so I will argue.

First, there are suggestions from loop quantum gravity that space and time are discrete, in that the quantum observables measuring spatial volume and temporal intervals have discrete spectra (Rovelli & Upadhya, 2001). One might think that the thesis that there is a smallest interval of time is incompatible with presentism. As for example Saint Augustine argues,

> the only time that can be called present is an instant ... that cannot be divided even into the most minute fractions ... . For if its duration were prolonged, it could be divided into past and future. (Augustine, 1961, Confessions, Book XI, Section 15)

My reply is that presentism need not require that the present lasts only an instant; instead presentism just has to require that the present cannot be divided into past and future, as St. Augustine specifies. If quantum gravity entails that the Planck time of about 10^{-43} s, for example, is the smallest interval of time, then the presentist can simply specify that that is how long the present lasts. It would be impossible to divide the present into past and future, since there would be no time intervals smaller than the Planck time.

Second, there are suggestions from both theories, but especially M theory, that spacetime is not part of fundamental reality, but just emerges in some classical limit. (For a discussion of this emergence, see Butterfield & Isham, 1999.) As Edward Witten puts it,

> 'spacetime' seems destined to turn out to be only an approximate, derived notion, much as classical concepts such as the position and velocity of a particle are understood as approximate concepts in the light of quantum mechanics. (Witten, 1996, p. 134)

Some presentists might believe that time and change have to be aspects of fundamental reality for presentism to be true. I maintain, though, that this is not an essential requirement of presentism. Presentism should not be understood as a theory about fundamental reality, it should be understood as a theory about time. Thus, if time is not part of fundamental reality, presentism is true as long as the time that emerges in the appropriate classical limit is time as described by presentists.

This leads us to the fundamental reason that M theory and loop quantum gravity are in fact incompatible with presentism. For M theory it is known, and for loop quantum gravity it is expected, that the spacetime theory that emerges in the classical limit is general relativity (see, e.g., Rovelli, 1998, pp. 5, 8). Thus, the time that emerges in the classical limit is not time as described by the presentist.

From the standpoint of the committed presentist, proponents of M theory and loop quantum gravity are simply making a mistake. Consider an analogy with quantum mechanics: proponents of the Bare theory — standard Schrödinger evolution with the eigenstate–eigenvalue link — argue that the Bare theory can account for the everyday beliefs we have about measurement outcomes (Albert, 1992, pp. 116–119; Barrett, 1994). Most people believe, though, that the Bare theory has a measurement problem, and hence look for ways of modifying it in order to save our everyday beliefs (Bub, Clifton, & Monton, 1998). Presentists would say that M theory and loop quantum gravity are in the same sort of situation as the Bare theory: they would say that M theory and loop quantum gravity are incompatible with some of our everyday beliefs, in this case our everyday beliefs about time. (Following Callender's distinction, some presentists would say that the theories are incompatible with our experience of becoming, while others would say that they are incompatible with our basic concept of time.) Thus, just as those who endorse our everyday beliefs about measurement outcomes support the development of acceptable alternatives to the Bare theory, so those who endorse presentist beliefs about time should support the development of acceptable alternatives to M theory and loop quantum gravity.

There is something problematic about the sort of image this brings to mind, of a wealthy presentist funding workshops for physicists to encourage them to develop presentist-friendly physical theories. Fortunately, there are other alternatives for presentists besides trying to change the minds of physicists. For a presentist who is not a scientific realist, there is little reason to be concerned, since such a presentist would not take physics to be providing a true account of the world. But there is even room for presentists who are scientific realists to be unconcerned. Such presentists could hold that, even though the aim of science is truth, we are not close yet. They might believe that there are many more scientific revolutions yet to come before we get to the true fundamental theory, and that at our current stage we are really not much closer to the truth than people were when Aristotelian physics was dominant. Such presentists would not take the fact that our current most popular theories of physics are incompatible with presentism to be evidence against presentism, just as they would not take the fact that Aristotelian physics is compatible with presentism to be evidence for presentism. They would hold that our current theories are so far from reality that we cannot take them to provide any guide to the fundamental nature of time.

Given that physics is currently moving in the direction of M theory and loop quantum gravity, presentism's future prospects do not look good, at least from the standpoint of scientific realists who take current developments in quantum gravity as getting us close to a true account of reality. Nevertheless, based on the existence of potentially viable theories of fixed foliation quantum gravity, I conclude that presentism is compatible with our most fundamental physics — for now.

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