Special Relativity, Time, Probabilism, and Ultimate Reality[1]

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Abstract

McTaggart distinguished two conceptions of time: the A-series, according to which events are either past, present or future; and the B-series, according to which events are merely earlier or later than other events. Elsewhere, I have argued that these two views, ostensibly about the nature of time, need to be reinterpreted as two views about the nature of the universe. According to the so-called A-theory, the universe is three dimensional, with a past and future; according to the B-theory, the universe is four dimensional. Given special relativity (SR), we are obliged, it seems, to accept (a modified version of) the B-series, four dimensional view, and reject the A-series, three dimensional view, because SR denies that there is a privileged, instantaneous cosmic "now" which seems to be required by the A-theory. Whether this is correct or not, it is important to remember that the fundamental problem, here, is not "What does SR imply?", but rather "What is the best guess about the ultimate nature of the universe in the light of current theoretical knowledge in physics?". In order to know how to answer this question, we need to have some inkling as to how the correct theory of quantum gravity incorporates quantum theory, probability and time. This is, at present, an entirely open question. String theory, or M-theory, seems to evade the issue, and other approaches to quantum gravity seem equally evasive. However, if probabilism is a fundamental feature of ultimate physical reality, then it may well be that the A-theory, or rather a closely related doctrine I call “objectism”, is built into the ultimate constitution of things.

1 Eventism versus Objectism

McTaggart, famously, distinguished two conceptions of time: the A-series, according to which events are either past, present or future; and the B-series, according to which events are merely earlier or later than other events. Elsewhere (Maxwell, 1968, pp. 5-9; 1985, pp. 29-36; 2001, pp. 249-52) I have argued that these two views, ostensibly about the nature of time, need to be reinterpreted as two views about the nature of the universe – the nature of the entities of which the universe is composed. According to the A-series view (or A-theory), which I have called objectism (and which is sometimes called presentism), the universe is three dimensional, with a past and future. The entities of which the universe is composed are *objects*, three dimensional entities which move and change, which can be created and destroyed, and which are spread out in space, but not in space-time. *Objects* in this sense may be very different from familiar stones and tables: the instantaneous state of a field might be an *object*. According to the B-series view (or B-theory), which I have called eventism, the universe is four dimensional. The basic entities of the universe are *events*, spread out and located in space-time rather than in space.

Objectism and eventism give different interpretations to space-time diagrams. According to eventism, a space-time diagram is a picture of a bit of the world itself, spread out as it is in space and time. According to objectism, a space-time diagram depicts facts about the world, but does not depict the world itself at all, which is three, and not four, dimensional. A four dimensional world-line of an object is, according to objectism, the history of that object, but not the object itself. Eventism puts spatial and temporal relations on a par; both are relations between the ultimate entities of the universe, *events*. Objectism draws a sharp distinction between spatial and temporal relations: whereas spatial relations are between *objects*, temporal relations are between *facts about objects* or, perhaps, *instantaneous states of objects*, or *histories of objects*, and not between *objects as such*.

In order to make sense of objectism, it is essential not to interpret it as adding what has sometimes been called "objective becoming" to eventism (or to McTaggart's B-series, or to the space-time or "block universe" view).[2] There are three quite distinct views to consider: (1) eventism - or the block universe view, (2) the block universe view plus "the present", which moves along the time line, thus creating "absolute becoming" and "the flow of time", and (3) objectism. (2) and (3) are quite different. These two views find (1), eventism or the block universe view, inadequate in quite different ways, and make quite different modifications to it. Consider a space-time diagram depicting the histories of objects moving through space for some duration of time. According to eventism, this can be taken to represent things as they really are. It is a picture of how things are (with two spatial dimensions missing). The universe really is spread out in space and time, and the space-time diagram depicts straightforwardly the bit of the universe it represents. According to (2), the space-time diagram of eventism leaves out one crucial element, namely "the present", and its motion along time. A spatial line needs to be added to the diagram (in reality a three dimensional space-like hyperplane), which moves along time from past to future, thus representing "absolute becoming". According to (3), namely objectism, by contrast, the space-time diagram of eventism leaves *everything* out, the entire universe. For the universe is three-dimensional, not four-dimensional. The entities of which it is composed – objects – are three dimensional. They are spread out in space, and have spatial relations between them, but are not spread out in time, and do not have temporal relations between them. Objects persist in time, have pasts and futures, come into existence and cease to exist, but none of this means that they are spread out in time. It is facts about objects, histories of objects – intellectual artefacts – that are "spread out" in time, not objects themselves. The space-time diagram of eventism must, according to objectism, be radically reinterpreted, so that it does not picture or depict anything, and certainly not a bit of the universe: instead it represents *facts about objects* much as a graph of, say, temperature against time might represent facts about objects but would not picture or depict objects themselves. Thus (2) and (3) make quite different modifications to the space-time picture of eventism. (2) adds "the present" and "the flow of time" to this picture, whereas (3) reinterprets the diagram as a representation of facts about objects, but is not a picture of objects or a bit of the universe at all. It cannot be because, according to objectism, objects and the universe are three, not four dimensional, and are not spread out in time in the way the diagram depicts. (For further clarification see Maxwell, 1968, pp. 5-9; 1985, pp. 29-36; 2001, pp. 249-52.)

This difference between (2), the time flow view, on the one hand, and (3), objectism, on the other hand, is crucial. For whereas the former view faces intractable problems about the nature of "the present" and "the flow of the present along time", objectism faces no such problems as it rejects, from the outset, the four dimensional, space-time picture of the block universe (except as a way of representing facts about objects). To repeat, according to objectism, the block universe view is defective, not because it leaves out "the now", and "the movement of the now along time" (or "absolute becoming"), but rather because it leaves out *everything*, *the entire universe* (and only represents facts about objects, histories of objects, facts about the universe). Given objectism, one might try to represent things happening by means of a spatial line, the present, moving along time, but nothing in reality corresponds to the line moving along time because, according to objectism, there is in reality no temporal dimension for the line to move along.

Thus, in order to make sense of objectism, it is essential not to interpret it as adding "the now", "the flow of time" and "becoming" to eventism (or to McTaggart's B-series, or the "block universe" view). It is tempting to do this, because common sense views about time tend to put eventism and objectism together incoherently to form a picture somewhat similar to "the flow of time" view. Common sense tends to think of the distant past in eventist terms, as "another place", but thinks of current events in objectist terms, the immediate past consisting of past facts about current objects and not being another temporal "place" in any sense at all. Such a common sense picture of time, incoherently combining eventism and objectism, can lead one to think that the "now", and "temporal becoming" must be added to McTaggart's B-series, or to the space-time or block universe view, to do justice to the way we experience time, in the present.[3] This incoherent admixture of eventism and objectism is sometimes taken, by proponents of the space-time or block universe view, to be the only potential rival to their view. They have no difficulty in demolishing this rival.[4] But the viable rival to eventism (the B-theory, or the space-time or block universe view) is *objectism*, not some incoherent admixture of eventism and objectism (the AB-theory) which has the objective present moving along spatialized time. The two rival views at issue, eventism and objectism, are best seen as rival views about the dimensionality of the universe, as I have indicated, and not, primarily, as rival views about the nature of time. In particular, objectism must not be identified with the view that there is something called "the objective now", or "temporal becoming", since this tends to appeal to the common sense "eventism plus objectism" view, just indicated, which is inherently incoherent.

2 Special and General Relativity, Eventism and Objectism

Do special and general relativity demand that one rejects objectism, and adopts eventism instead? It is striking that Einstein formulated special relativity (SR) originally, in 1905, in objectist terms, reference frames being characterized in terms of rods and clocks, persisting objects. It was only with Minkowski's reformulation of SR, in 1908, that the space-time view came to the fore. "Henceforth space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality" Minkowski resoundingly declared (Lorentz et al., 1952, p. 75). Einstein initially dismissed Minkowski's contribution as "superfluous learnedness" (Pais, 1982, p. 152), and remarked that now that the mathematicians had got their hands on his theory, he no longer understood it himself. But subsequently he adopted Minkowski's space-time view as an essential step towards creating his second great theory – general relativity (GR).

And it seems that SR does indeed imply that we are obliged to reject objectism and accept eventism. For if objectism is true, the universe is made up of three-dimensional objects, persisting and changing. At any instant, here and now, there must be a cosmic-wide state of the universe, indeed *the universe* at that instant. But this clashes with SR. Observers (or objects) in relative motion here and now have, associated with them, different cosmic-wide presents or "nows". In denying that there is any such thing as a privileged reference frame, SR denies that there is, associated with any space-time point or event, a privileged, cosmic-wide instantaneous "now" which divides all other events into those that are "past" and "future". Any space-like hyperplane that passes through the point or event in question is as good an instantaneous "now" as any other. Thus SR, if true, rules out objectism, and demands that eventism must be accepted - a version of eventism that holds that space-time is Minkowskian.[5]

But is SR true? If GR is true, then SR is false (since SR asserts that space-time is flat while GR asserts that, in the presence of energy, it is curved). But appealing to GR instead of SR does not help the case for objectism, since GR would seem to be just as incompatible with objectism as SR.

But is GR true? We seem to have rather good grounds for holding that it is false. Efforts to reconcile GR and quantum theory (QT) have not succeeded. All attempts known to me to unify GR and QT, or GR and the quantum field theories of the "Standard model" (SM), such as string theory (or M theory), and loop quantum gravity, if successful, would imply that GR is false. GR would emerge as an approximation when certain limits are taken, somewhat as Newtonian theory (NT) emerges from GR as an approximation, or Kepler's laws of planetary motion emerge from NT as an approximation. This is a standard state of affairs in theoretical physics. Almost always in the history of physics, when a new theory, T, unifies two predecessor theories, T_1 and T_2, T reveals that T_1 and T_2 are strictly speaking false (even though both T_1 and T_2 make many true, somewhat imprecise empirical predictions).

Granted, then, that we seek to discover which of eventism and objectism is *true*, and granted that both SR and GR are *false*, the important question becomes: Does the true theory of quantum gravity, like SR and GR, imply that objectism is false?

It is possible that the true theory of everything, T, may not, of itself, decide which of eventism and objectism is true. From the standpoint of physics alone, eventism must always, it would seem, remain a possibility.[6] It would seem, then, that either T is such that it can be reconciled with either eventism or objectism, or T is such that it implies that objectism is false. Which of these options is true?

3 The True Theory of Everything and Aim-Oriented Empiricism

This question may seem hopeless. In the absence of the true theory of quantum gravity, or the true theory of everything, it may seem that there is nothing that can be said about their character. Only when a candidate theory of quantum gravity, or of everything, has been formulated, tested and corroborated will we be in a position to assess objectism with respect to these theories.[7] As things are at present, we have no theoretical scientific knowledge about the ultimate nature of the physical universe.

Elsewhere, I have argued at length that the standard empiricist conception of science that is being presupposed here is untenable (Maxwell, 1974; 1984, ch. 9; 1993; 1998;

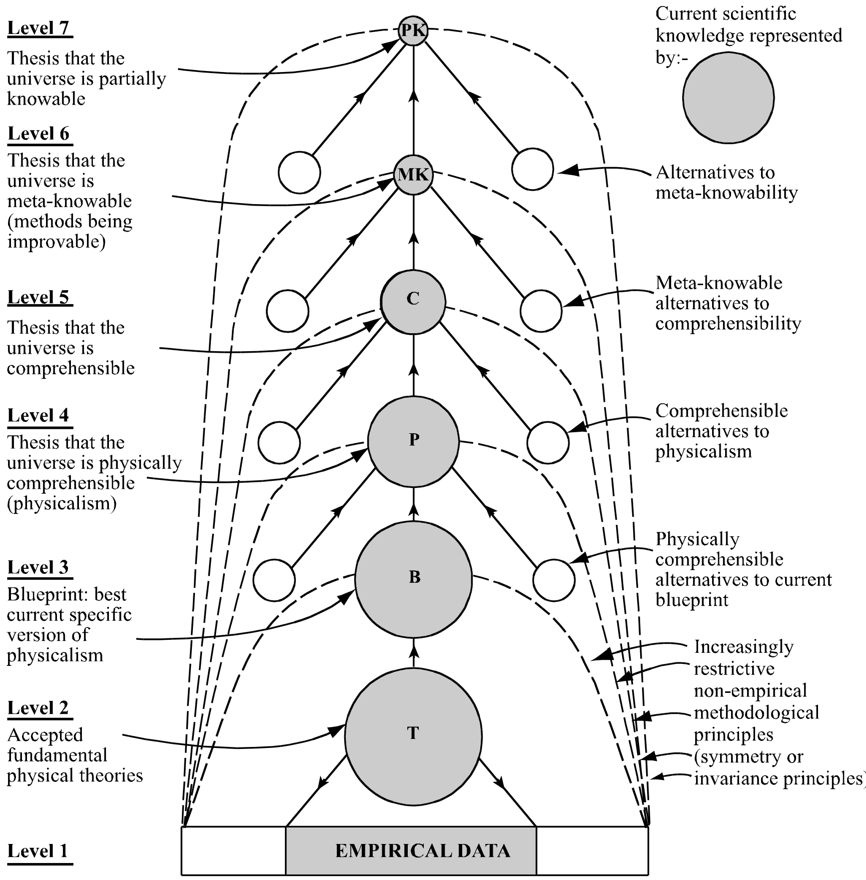

Diagram: Aim-Oriented Empiricism (AOE)

1999; 2000; 2001, ch. 3 and app. 3; 2002a; 2002b, 2004b; 2005). Persistent acceptance of unified theories, and persistent rejection (or rather failure even to consider) empirically more successful but disunified theories, means that science accepts, as a part of theoretical knowledge, a metaphysical thesis about the universe which asserts that the universe has a unified dynamic structure (to some degree at least). In order to do justice to this point, physics needs to be construed as accepting, as a part of scientific knowledge, a hierarchy of metaphysical theses concerning the knowability and physical comprehensibility of the universe, which become increasingly insubstantial, and thus increasingly likely to be true, as one ascends the hierarchy: see diagram. Low down in this hierarchy there is the thesis that the universe has a unified dynamic structure (which I call "physicalism"). Physicalism is thus an integral part of current theoretical scientific knowledge, more secure indeed than any theory however empirically successful, such as SR, GR, QT or SM.

Granted this conception of physics, which I call "aim-oriented empiricism" (AOE), it is to be expected that physics should advance from one false theory to another. If physicalism is true, then no dynamic theory of restricted scope (which cannot immediately be generalized to become an accurate theory of everything) can be precisely true of any restricted range of phenomena. Granted physicalism, if a physical theory is precisely true of anything, it must be precisely true of everything.

The conclusion we should draw from all this is that physics does, now, possess (conjectural) theoretical knowledge about the ultimate nature of reality.[8] A proper, basic task for philosophy of physics, indeed, is to speculate, within the general framework of AOE, about the nature, the general character, of the true theory of everything, the ultimate nature of physical reality. (In moving from standard to aim-oriented empiricism, the nature of the relationship between science and philosophy of science is transformed: the philosophy of science ceases to be a meta-discipline, and becomes an integral part of the scientific enterprise itself.)

It is thus entirely proper (and not hopeless at all) to consider whether the true theory of quantum gravity, or of everything, will imply that objectism is false.

4 Time and Probabilism

SR and GR, we have agreed, rule out objectism. Both these theories will be derivable from the true theory of quantum gravity, or of everything, T, as approximations. Does this not make it likely that T, too, will rule out objectism? What grounds might there be for thinking otherwise? There are two.

The first has to do with time. As Chris Isham has emphasized especially (see Isham, 1993; 1997), time poses an especially severe problem for attempts to develop quantum gravity (and thus the true theory of everything, T). This is partly due to the fact that time figures in quite different ways in GR and QT, even Lorentz invariant QT, or quantum field theory (QFT). As far as GR is concerned, time is a part of space-time, that within which events are, as it were, embedded. As far as QT is concerned, time is something external to the quantum system in question, measured by an external clock. Whereas GR presupposes eventism, QT is compatible with objectism. (As I pointed out above, no physical theory can presuppose objectism in the sense that it cannot be formulated in such a way as to be compatible with eventism.)

It may be objected that QFT cannot be compatible with objectism, since SR contradicts objectism, and QFT, of course, has SR built into it. But it must be remembered that orthodox QT, whether Lorentz invariant or not, is a theory about the results of performing measurements on quantum systems prepared to be in certain quantum states. The quantum states, and the quantum fields of QFT, cannot be taken seriously as physical entities existing in space and time independently of methods employed to prepare and measure them. QT and QFT have instrumentalism built into them. Severe problems arise when it is demanded that the measurement process itself should be Lorentz invariant. It is by no means clear that this demand can be fulfilled.[9]

The only consistent Lorentz invariant treatment of quantum measurement known to me is Gordon Fleming's "hyperplane dependent" theory: see Fleming (1989). This entails a radical departure from Minkowskian space-time, however, in that it requires that the basic space-time entity is the space-like hyperplane rather than the space-time point. According to the theory, what exists in any small space-time region may depend on what hyperplane it is considered to lie on. Reality is, according to the theory, highly non-local in character, a dramatic departure from SR as ordinarily understood.

If Fleming's speculative hyperplane dependent theory is put on one side, then QFT, including measurement, cannot be held to be fully in accord with SR. QFT, unlike SR and GR, cannot be regarded as presupposing eventism and unambiguously excluding objectism.

Insofar as it is true that the different ways in which time figures in GR and QT amounts to GR presupposing eventism and QT failing unambiguously to exclude objectism, and taking into account that no satisfactory unification of GR and QT has yet been formulated, it must be an open question as to whether the eventism of GR, or the objectism of QT, as a possibility at least, will win out in the unifying theory.

The second, and in my view stronger, ground for holding that T (quantum gravity or the true theory of everything) may not rule out objectism has to do with *probabilism*. Elsewhere I have argued at length that QT needs to be interpreted as a fundamentally probabilistic theory, and I have put forward such a version of QT, testably distinct from orthodox QT (see Maxwell, 1976; 1982; 1988; 1994; 1998, ch. 7; and 2004a). This version of QT is sketched below in the appendix: for other fundamentally probabilistic versions of QT see (Ghirardi and Rimini, 1990; and Penrose, 1986). By a "fundamentally probabilistic" theory I mean one which postulates real, objective probabilistic transitions in nature, not specifically tied to measurement. If a fundamentally probabilistic version of QT turns out to be "correct", to the extent that it is free of the conceptual defects which plague orthodox QT, and meets with greater empirical success than orthodox QT, then there are strong grounds for holding that nature herself is probabilistic, especially in view of the staggering empirical success of QT.

There are other grounds for taking very seriously the thesis that nature (i.e. the true theory of everything) is fundamentally probabilistic (i.e. probabilism is true). Spontaneous symmetry breaking is an essential feature of the quantum electroweak theory of Weinberg and Salam. Basing their considerations on this feature of the theory, and on the empirical success of the theory, physicists and cosmologists take very seriously the idea that after the big bang the cosmos has undergone one or more spontaneous symmetry breaking episodes. It is, for example, a feature of versions of inflationary cosmology. But spontaneous symmetry breaking demands probabilism. Insofar as we take spontaneous symmetry breaking seriously, we take probabilism seriously as well.

The point now is this. If nature is fundamentally probabilistic in character, as well as being quasi quantum mechanical, then it is not unreasonable to suppose that there are cosmic-wide instantaneous "nows" associated with probabilistic transitions that are entirely physical in character. Only very subtle experiments, not yet performed, might be able to detect the existence of these cosmic "nows".[10] If they do exist, then T (which postulates them) does not exclude objectism. Objectism only appears to be ruled out if we restrict our attention to SR and GR, which fail to do justice to the probabilistic character of nature, and thus fail to do justice to that feature of nature which makes objectism viable.

In creating SR, Einstein took determinism for granted. Nevertheless, SR is not incompatible with probabilism as such. SR could, it seems, accommodate a version of probabilism which is such that all probabilistic events are highly localized throughout. But suppose probabilistic events fail to satisfy this condition. In particular, suppose they take the following quasi quantum mechanical form. A physical system, S, is spread throughout some spatial region R (as the Ψ-function of QT is spread out spatially); S then interacts with a much more localized system, s, confined to a spatial region r somewhere in R. The interaction produces the physical condition for a probabilistic transition to occur, and S is localized, instantaneously and probabilistically, within r. In this case a reference frame, F_S say, which depicts the "collapse of the wave packet" of S, the probabilistic localization of S from R to r, as instantaneous, will make sense of the probabilistic transition. But all other frames, moving with respect to F_S, will fail to do this. For in these other frames, physical parts of S will begin to collapse towards r before the physical condition for this collapse to occur have been met. Physical occurrences will, as it were, anticipate future states of affairs. For such a fundamentally probabilistic theory, then, even though it is Lorentz invariant in other respects, only F_S (and frames stationary with respect to F_S) can make physical sense of the probabilistic transition. The probabilistic transition in effect defines a unique instantaneous "now". It is reasonable to suppose that, for such a Lorentz invariant fundamentally probabilistic theory, all such instantaneous "nows" would add up to a unique family of "nows". The fundamentally probabilistic version of QT that I have sketched in the appendix, and formulated in more detail elsewhere (Maxwell, 1976, 1982, 1988, and especially 1994 and 1998, ch. 7, and 2004a) is precisely of this type.[11] So too are other probabilistic versions of QT (see Ghirardi and Rimini, 1990; Penrose, 1986).

What really goes on, at the quantum mechanical level, during the process of quantum mechanical measurement, is still a mystery. It is conceivable, however, that the fundamentally probabilistic version of QT that I have proposed, or a version of QT of the type indicated in the previous paragraph, is correct. If so, only experiments that may be very difficult to perform will detect the difference between orthodox QT and these fundamentally probabilistic versions of QT. Cosmic-wide instantaneous "nows" may, in other words, exist and may be detectable experimentally, but only by experiments not so far performed. Experiments required to differentiate the version of QT I have proposed from orthodox QT are, as I have indicted, fiendishly difficult to perform, and have not yet been performed (to my knowledge), even though they are, in principle, possible. It is in this way that SR's denial of the existence of a unique family of instantaneous "nows", required for objectism to be viable, may be misleading. Despite this denial, such a family, associated with probabilistic transitions, may well exist. Despite what SR implies, objectism may well be true.

As I understand the situation, GR does not deny probabilism either. But, in order to be compatible with GR, probabilistic transitions would need to be both highly localized throughout, and such that they do not produce instantaneous changes in the gravitational field. (Unlike SR, GR is a deterministic dynamical theory in its own right, and thus cannot allow probabilistic transitions in the gravitational field to occur.) Probabilistic transitions of the kind considered above do not satisfy these conditions, and are thus incompatible with GR. If it is reasonable to hold that the correct fundamentally probabilistic version of QT, when made compatible with SR (insofar as it can be) postulates a unique family of instantaneous "nows", the same would presumably hold for such a theory formulated within the context of GR.

5 In Defence of Objectism

Objectism captures the way we ordinarily construe the world. Eventism (the B-theory, the space-time view, the block universe) does extreme violence to the way we ordinarily conceive of the world. Almost everything that we ordinarily take for granted becomes a kind of massive illusion, a shared hallucination, if eventism is true. Such things as: the existence of objects; the supreme reality of the present and the non-existence of the past and the future (except as past and future facts about what exists now); the three-dimensionality of a world in which things persist and change, four dimensional histories being artificial constructs, facts about things rather than things themselves; people acting to change the future and not being merely embedded in a space-time that is just atemporally, “there” - all these things, that we ordinarily take for granted, becomes illusory if eventism is true. There need to be strong grounds indeed for abandoning objectism in favour of eventism (the B-theory). If such strong grounds seem to arise from science, then we should bravely face the world as it appears to be, and resign ourselves to living with eventism. But if such strong grounds subsequently collapse, and there appears to be no good scientific reason whatsoever for preferring eventism to objectism, we should not - as tends to happen in such situations - continue to accept, or even take seriously, eventism out of a kind of intellectual inertia. Grounds for believing in eventism having collapsed, we should instantly reject this profoundly counter-intuitive view and return to objectism.

The only scientific grounds - the only grounds - for preferring eventism to objectism come from SR and GR. But there are also reasons for doubts, as I have indicated. QT provides grounds for holding that nature is fundamentally probabilistic. If it is, and if quantum gravity, or the true theory of everything, postulates cosmic wide instantaneous “nows”, a unique family of space-like hypersurfaces on which probabilistic transitions occur, then the “strong grounds” for rejecting objectism and accepting eventism collapse. In these circumstances we should reject eventism and return to objectism. We should not continue to adopt eventism when all reasons to prefer this profoundly counter-intuitive doctrine have collapsed, out of nothing more than a kind of intellectual inertia.

5 Probabilistic Dynamic Geometry

I conclude with what may well be a very naïve remark concerning quantum gravity.

As I have argued elsewhere (Maxwell, 1993, pp. 275-305), Einstein put a quite specific (if fallible) method of discovery[12] into practice in discovering SR and GR. This involves picking two clashing, empirically highly successful theories, T_1 and T_2, extracting a basic principle, P_1 and P_2, from each, these principles being such that they conflict, in an attempt to get at the root of the clash between the two theories. Some modification is then made, either to P_1 or P_2, or to some other part of physics, which renders P_1 and P_2 mutually compatible, these two principles then being taken as the kernel of the new, unifying theory. Thus SR arose from the conflict between NT and classical electrodynamics (CE). From NT Einstein took the restricted principle of relativity, (P_1); from CE he took the light postulate (P_2). Adjustments to Newtonian conceptions of space and time rendered P_1 and P_2 compatible, which became the two basic postulates of SR. GR arose out of the conflict between SR and NT; P_1 is SR itself; P_2 is the principle of equivalence. These are then deployed to reveal that gravitation curves space, or rather space-time, which in turn suggests the key idea of GR that gravitation *is* the curvature of space-time.

This method of discovery should be employed to discover quantum gravity. The two theories are GR and QT (or QFT or SM). If QT is interpreted to be fundamentally probabilistic, we at once have the basic clash between the two theories: determinism versus probabilism. From GR we take deterministic, dynamic space-time geometry, from QT we take probabilism – characteristically quantum mechanical probabilism involving non-local probabilistic transitions. The synthesis requires the development of some kind of probabilistic, dynamic, space-time geometry. This requires, we may surmise, the specification of space-like hypersurfaces on which probabilistic transitions occur - these hypersurfaces forming a unique foliation of space-time, and constituting successive cosmic instantaneous "nows". Do we suppose, with Penrose, that space-time has a definite curvature, and permits quantum systems to evolve into superpositions which depart somewhat from the actual curvature until this discrepancy becomes, as it were, intolerable, and collapse occurs? Or do we suppose that something like superpositions of three dimensional spaces with different curvatures evolve and then collapse into one or other such curved space, in each case on some definite space-like hypersurface? Or is there some other way in which the basic idea of probabilistic dynamic geometry can be realized which, perhaps, leads to the correct theory? If probabilistic QT and deterministic GR can be unified correctly, so as to retain the probabilism of QT and the dynamic geometry of GR, it may well be that the resulting theory will render objectism a viable option. If it is, then it deserves to be accepted.

6 Appendix: Fundamentally Probabilistic Quantum Theory (PQT)

The thesis of this paper might be summed up like this. How seriously we should take the ontological implications of Minkowskian space-time depends crucially on how QT is to be interpreted. If QT is fundamentally probabilistic, and this probabilism is retained by the true theory of everything (with probabilistic transitions occurring on cosmic-wide space-like hypersurfaces) then the case for eventism and the space-time viewpoint would collapse. With this in mind, I now sketch the fundamentally probabilistic version of QT I have spelled out in more detail elsewhere (Maxwell, 1976; 1982; 1988; 1994; 1998, ch. 7; and 2004a).

The basic idea is that probabilistic transitions occur whenever new particles, bound systems or stationary states are created as a result of inelastic collisions. That is, whenever, as a result of an inelastic interaction, a system of interacting "particles" creates new "particles", bound or stationary systems, so that the state of the system goes into a superposition of states, each state having associated with it different particles or bound or stationary systems, then, when the interaction is nearly at an end, spontaneously and probabilistically, entirely in the absence of measurement, the superposition collapses into one or other state.

The problem, here, is to specify precisely "when the interaction is nearly at an end". This can be done as follows. Consider the toy inelastic interaction:-

$$
\begin{aligned}
a + b + c \;\rightarrow\; & a + b + c \qquad (A)\\
& a + (bc) \qquad (B)
\end{aligned}
$$

Here, a, b and c are spinless particles, and (bc) is the bound system. Let the state of the entire system be $\Phi(t)$, and let the asymptotic states of the two channels (A) and (B) be $\psi_A(t)$ and $\psi_B(t)$ respectively. Asymptotic states associated with inelastic interactions are fictional states towards which, according to OQT, the real state of the system evolves as $t \rightarrow +\infty$. Each outcome channel has its associated asymptotic state, which evolves as if forces between particles are zero, except where forces hold bound systems together.

According to OQT, in connection with the toy interaction above, there are states $\phi_A(t)$ and $\phi_B(t)$ such that:

(1) For all t, $\Phi(t) = c_A\phi_A(t) + c_B\phi_B(t)$, with $|c_A|^2 + |c_B|^2 = 1$;
(2) as $t \rightarrow +\infty$, $\phi_A(t) \rightarrow \psi_A(t)$ and $\phi_B(t) \rightarrow \psi_B(t)$.

The idea is that at the first instant t for which $\phi_A(t)$ is very nearly the same as the asymptotic state $\psi_A(t)$, and $\phi_B(t)$ is very nearly the same as $\psi_B(t)$, then the state of the system, $\Phi(t)$, collapses spontaneously either into $\phi_A(t)$ with probability $|c_A|^2$, or into $\phi_B(t)$ with probability $|c_B|^2$. Or, more precisely:

Modified Born Postulate: At the first instant for which $|\langle\psi_A(t)|\phi_A(t)\rangle|^2 > 1 - \varepsilon$ or $|\langle\psi_B(t)|\phi_B(t)\rangle|^2 > 1 - \varepsilon$, the state of the system collapses spontaneously into $\phi_A(t)$ with probability $|c_A|^2$, or into $\phi_B(t)$ with probability $|c_B|^2$, ε being a universal constant, a positive real number very nearly equal to zero.

The evolutions of the actual state of the system, $\Phi(t)$, and the asymptotic states, $\psi_A(t)$ and $\psi_B(t)$, are governed by the respective channel Hamiltonians, H, H_A and H_B, where:-

$$H = -\left(\frac{\hbar^2}{2m_a}\nabla_a^2 + \frac{\hbar^2}{2m_b}\nabla_b^2 + \frac{\hbar^2}{2m_c}\nabla_c^2\right) + V_{ab} + V_{ac} + V_{bc}$$

$$H_A = -\left(\frac{\hbar^2}{2m_a}\nabla_a^2 + \frac{\hbar^2}{2m_b}\nabla_b^2 + \frac{\hbar^2}{2m_c}\nabla_c^2\right)$$

$$H_B = = -\left(\frac{\hbar^2}{2m_a}\nabla_a^2 + \frac{\hbar^2}{2m_b}\nabla_b^2 + \frac{\hbar^2}{2m_c}\nabla_c^2\right) + V_{bc}$$

Here, m_a, m_b, and m_c are the masses of "particles" a, b and c respectively, and $\hbar = h/2\pi$ where h is Planck's constant.

The condition for probabilistic collapse, formulated above, can readily be generalized to apply to more complicated and realistic inelastic interactions between "particles".

According to this micro-realistic, fundamentally probabilistic version of quantum theory, the state function, $\Phi(t)$, describes the actual physical state of the quantum system, from moment to moment. Quantum systems may be called "propensitons". The physical (quantum) state of the propensiton evolves in accordance with Schrödinger's time-dependent equation as long as the condition for a probabilistic transition to occur does not obtain. The moment it does obtain, the state jumps instantaneously and probabilistically, in the manner indicated above, into a new state. (All but one of a superposition of states, each with distinct "particles" associated with them, vanish.) The new state then continues to evolve in accordance Schrödinger's equation until conditions for a new probabilistic transition arise.

Propensiton quantum theory (PQT), as we may call this micro-realistic, fundamentally probabilistic version of quantum theory, can recover all the experimental success of OQT. This follows from four points. First, OQT and PQT use the same dynamical equation, namely Schrödinger's time-dependent equation. Secondly, whenever a position measurement is made, and a quantum system is detected, this invariably involves the creation of a new “particle” (bound or stationary system, such as the ionisation of an atom or the dissociation of a molecule, usually millions of these). This means that whenever a position measurement is made, the conditions for probabilistic transitions to occur, according to PQT, are satisfied. PQT will reproduce the predictions of OQT (given that PQT is provided with a specification of the quantum state of the measuring apparatus). Thirdly, all other observables of OQT, such as momentum, energy, angular momentum or spin, always involve (i) a preparation procedure which leads to distinct spatial locations being associated with distinct values of the observable to be measured, and (ii) a position measurement in one or other spatial location. This means that PQT can predict the outcome of measurements of all the observables of OQT. Fourthly, insofar as the predictions of OQT and PQT differ, the difference is extraordinarily difficult to detect, and will not be detectable in any quantum measurement so far performed.

In principle, however, OQT and PQT yield predictions that differ for experiments that are extraordinarily difficult to perform, and which have not yet, to my knowledge, been performed. Consider the following evolution:-

	collision	superposition	reverse collision	
		a + b + c		
a + b + c	$\longrightarrow$		$\longrightarrow$	a + b + c
		a + (bc)		
(1)	(2)	(3)	(4)	(5)

Suppose the experimental arrangement is such that, if the superposition at stage (3) persists, then interference effects will be detected at stage (5). Suppose, now, that at stage (3) the condition for the superposition to collapse into one or other state, according to PQT, obtains. In these circumstances, OQT predicts interference at stage (5), whereas PQT predicts no interference at stage (5), (assuming the above evolution is repeated many times). PQT predicts that in each individual case, at stage (3), the superposition collapses probabilistically into one or other state. Hence there can be no interference.

If this fundamentally probabilistic version of QT (or something like it) is correct, and the probabilism of the theory is preserved intact in quantum gravity and the true theory of everything (with probabilistic transitions occurring on successive cosmic-wide space-like hypersurfaces), this would suffice to kill the case for eventism and the space-time viewpoint.

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Notes

1. I would like to thank Michael Lockwood and Leemon McHenry for their comments on an earlier version of this paper.
2. This and the next paragraph have been added in response to a request for clarification by a referee.
3. On this view, the two views should be known, not as the A-theory and the B-theory, but rather the AB-theory and the B-theory, an observation due to Michael Lockwood (personal communication).
4. See for example (Grünbaum, 1964, ch. 10).
5. This conclusion can be avoided if SR is reinterpreted in such a way that it does not deny the existence of a privileged reference frame, but asserts, merely, that it is not discoverable empirically.
6. The only argument known to me from physics, or the philosophy of physics, for excluding eventism has to do with the possibility of interpreting physical theories essentialistically, as attributing necessitating properties to physical entities, there thus being something in nature which ensures that the regularities of physical law are obeyed. In (Maxwell, 1968) I argued that essentialism presupposes objectism. Subsequently I changed my mind, and argued that one can make sense of essentialism given either objectism or eventism (Maxwell, 1998, pp. 141-150; see especially p. 150). It is possible, however, that the earlier argument is the correct one, and the later argument deserves to be rejected.
7. We can, of course, consider string (or M) theory, and loop quantum gravity, in their present unsatisfactory state, and consider whether these theories are such as to rule out objectism. Insofar as these theories reproduce the way GR declares all space-like hypersurfaces to be equally legitimate instantaneous "nows", these theories rule out objectism for the same reason as GR does. But if a theory of this type picks out a family of cosmic-wide, space-like hypersurfaces as representing uniquely successive cosmic "nows", then the theory fails to exclude objectism (at least for the reasons given in section 2).
8. This (conjectural) scientific knowledge about ultimate reality is based on current (and past) research, as a referee has correctly pointed out. But the crucial point is that what we are entitled to take to be our current knowledge about ultimate reality differs dramatically, depending on whether we accept standard empiricism (SE) or aim-oriented empiricism (AOE). Granted SE, we have no such current knowledge, as we have good grounds for believing all our current fundamental physical theories are false. Granted AOE, we have one highly significant item of knowledge: physicalism.
9. For an excellent account of the problems encountered in reconciling quantum theory and special relativity see Maudlin (2002).
10. The fundamentally probabilistic version of QT that I have put forward elsewhere (Maxwell, 1976; 1982; 1988; 1994; 1998, ch.7; 2004b) is in principle experimentally distinct from orthodox QT. The relevant crucial experiments are very difficult to perform and have not, to my knowledge, yet been performed. These are the kind of as yet unperformed "very subtle experiments" that might reveal the existence of cosmic-wide hypersurfaces on which probabilistic events occur.

11. So far this “propensiton” version of QT has been formulated only for non-relativistic QT; its relativistic generalization has not yet been done.
12. This method of discovery, created in scientific practice by Einstein, is an important ingredient of aim-oriented empiricism: see (Maxwell, 1998, p. 29, pp. 159-163 and 219-223; 2004b, pp. 34-39).