Time and Reality

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by

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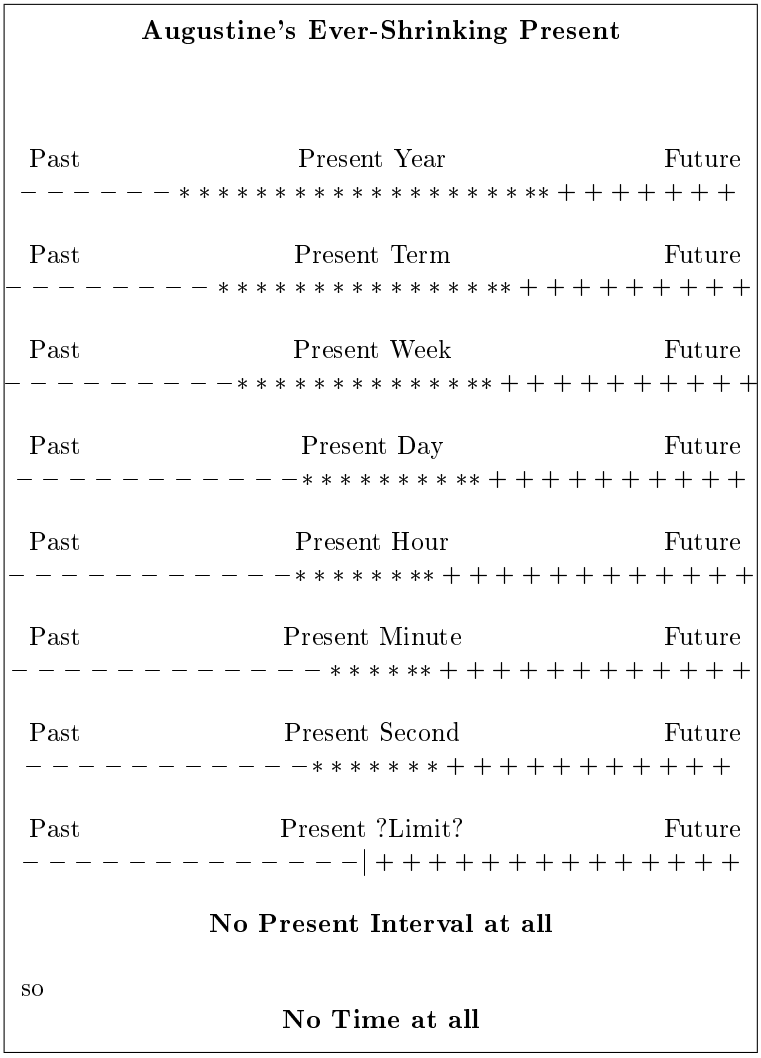
It is mandatory to start with St Augustine, whose famous remark: *si nemo me ex me quaerat, scio; si quaerenti explicare velim, nescio.* (*Confessions* XI, xiv)
(If nobody asks me, I know what it is, but if I would explain it to someone, I find myself in ignorance) resonates with all who have tried to think about time.

But for me it is singularly appropriate, for it was Augustine's argument which showed me the way out of the sterile linguistic philosophy that was *de rigeur* in the Oxford of my youth.

Augustine starts by putting forward an argument which he got from Aristotle—I call it the argument of the ever-shrinking present—to throw doubt on the objective existence of time. Although we talk of the present, we find when we think about it that whatever interval we had called the present, it is not really all present but is partly future and partly past. The present year is the year 2000 AD, but January and part of February are already past and April is yet to come.



And similarly with months, weeks, days, hours, minutes and seconds, until we seem forced to the conclusion that there is no time that is truly present, and so no real time at all. But what we have actually shown is that what counts as the present interval depends on context, and contexts vary. There is no absolute present interval, but rather a sequence of nested intervals that converge on an instant, the present instant, much as Cantor, in his definition of a real number, constructed a

Cauchy sequence of nested intervals, converging to a punctiform limit. St Augustine's mistake is to use the words for 'present', 'past' and 'future' as nouns, instead of adjectives. As an adjective, 'the present' needs a noun, such as 'year', month', or 'week', and once such a noun is provided, the pressure to keep changing the noun is easier to resist. More fundamental, however, is the distinction between intervals, which are stretches of time, and instants, which are, as it were temporal points. Once we have this distinction, we see that what the argument of the Ever-Shrinking Present really establishes the continuity of time: time is a continuum, like the real numbers.

Augustine's Argument against the Reality of Time

1. Only the Present is Real.
2. No temporal interval is altogether Present.
3. Only an instant can be properly called Present
4. An instant does not have extension
5. Time does have extension
6. Time is not Real

To adopt Dedekind's, rather than Cantor's approach, there is no gap with temporal instants between those that are past and those that are yet to come, as there is with *rational* numbers between those whose squares are less than 2 and those whose squares are more than 2. There is no chink between today and tomorrow, between the past and the future intervals. The present instant is a boundary of both, not only separating them, but also uniting them in a continuous whole stretch of time. Thus the Ever-Shrinking Present does not disprove the existence of time, but establishes a thesis of the Ever-Present Present, which for those philosophers who believe that only present time is real, proves that time always exists.

In Continuous Time, Present Actuality is Always Present

This also can be seen as a back-handed argument for the continuity of time: only if time is continuous, can we be sure that it always exists.[1] There are other arguments from the natural sciences for the continuity of time; and if time is continuous, space must be continuous too.

Arguments for the Continuity of Time

1. **Ever-shrinking Present**
2. **Ever-present Present**
3. **Assumptions of Science**

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The first two are purely conceptual arguments, about how we think—have to think—about time.

1. Ever-shrinking Present → Cantor's real numbers
2. Ever-present Present → Dedekind's real numbers

—o0o—

3. Physical Science is formulated in terms of real numbers, and on occasion uses irrational numbers to date particular instants.

Science could conceivably be better expressed in ways that did not presuppose real numbers—quantum mechanics might lead us to adopt a fuzzy realism with an Intuitionist theory of numbers. But present theories, so long as they are not superseded, support time's being continuous.

[1] See further below on the uniqueness of the present.

Agency

Having aired doubts whether time really exists, St Augustine gives his own account, saying that time is a *distentio* a stretching (*Confessions* XI, xxiii), a *distentio animi* a stretching out of the mind (*Confessions* XI, xxvi). The word *distentio* stretch, suggests not only that time is an interval, but that it is dynamic, concerned with what we intend, attempt, and actually do. Like Gregory of Nyssa, who has a doctrine of ἐπέκτασις (*epektasis*), St Augustine quotes St Paul's letter to the Philippians (3:14), about our leaving behind the past, and reaching out to the future. It is an agent-centred, activist, and inherently tensed view of time. It is a reasonable place to start from. Although, as we shall see, there are arguments in favour of a different, static, view, it is reasonable for me to start from where I am; and if I start from me, the most fundamental feature of being me, and being in a position to use the first person, is that I am a do-er, and do, and intend to do, deeds. Descartes cogitated, and concluded that he existed. I, when I meditate on my being, have to admit that I am an agent, who aspires, attempts, acts and achieves.

Not just
Cogito ergo Sum
but
Ego ergo Ago

If I am an agent, I have to envisage the future in making up my mind about what I am going to do. I must imagine what the outcome of my actions will be. I decide to go to the pub. It would not be an intelligible decision unless I have some idea of what being at the pub will be like: a bar where I can buy some beer; a barmaid I can chat up; a chum I can talk to; the publican, who will have a message for me. An agent must, at least to some limited extent, be able to *project* himself into possible future situations which might result from his actions. But if I have to think of possibilities in the future, and consider what things would be like if I were to bring them about, I have also to be able to think of myself in some future situation, thinking in that situation of possibilities in the future, and considering what things would be like, if I were then to bring them about, That is, as of now, I must be able not only to envisage possibilities, but also of my envisaging at some later date further possibilities, which I can take into consideration as possibilities now. That is to say that for an agent considering what to do, possible possibilities are possible. Hence the modal logic of the future possibilities open to an agent is **S4**-ish, since the proposition:

$$\Diamond\Diamond p \rightarrow \Diamond p$$

is the contrapositive equivalent of 4, the characteristic thesis of **S4**. Instead of considering possible worlds *simpliciter*, Kripke considered *accessible* worlds, with different relations of accessibility.
If the accessibility relation is serial (never comes to a dead end), the modal logic is **D** whose characteristic thesis is $\vdash \Box p \rightarrow \Diamond p$: if the accessibility relation is reflexive, the modal logic is **T** whose characteristic thesis is $\vdash \Box p \rightarrow p$: if the accessibility relation is symmetric, the modal logic is **B** whose characteristic thesis is $\vdash \Diamond\Box p \rightarrow p$: if the accessibility relation is transitive and reflexive, the modal logic is **S4** whose characteristic thesis is $\vdash \Box p \rightarrow \Box\Box p$: if the accessibility relation is an equivalence relation (or is both euclidean and reflexive), the modal logic is **S5** whose characteristic thesis is $\vdash \Diamond\Box p \rightarrow \Box p$. The modality of the future is **S4**-ish, with a transitive accessibility relation, expressing the fact that possible possibles are possible, or, equivalently, that future futures are future. But it is not exactly **S4**, which has the thesis $\vdash \Box p \rightarrow p$, with the accessibility relation for **S4** being reflexive as well as transitive, whereas it does not follow from something's being going to happen in all future possible worlds that it is happening now. The accessibility relation for future modality is transitive, but not reflexive, and the appropriate modal logic for the future is not exactly **S4**, though it has 4 as a thesis. This suggests a tree-like structure for the future. The agent envisages alternative courses of action, and then, projecting himself into what would happen for each choice he might make, sees further choices to be made, and further possibilities that might eventuate. See Tree1.pdf on p.9 at end of this text for the choices facing an undergraduate in his final year.

What about the past? The past for an agent is different from the future. So the accessibility relations for the future and the past cannot be symmetric, and the accessibility relation for the past will be the converse of the accessibility relation for the future, but not identical to it. But since the accessibility relation for the future is transitive, it follows that the converse relation is transitive too.

It is natural to write past modalities, as $\Box^{-1}$ and $\Diamond^{-1}$.[2] In the modal logic for the past, we shall have the characteristic S4-ish theses:

$$\vdash \Diamond^{-1}\Diamond^{-1}p \rightarrow \Diamond^{-1}p$$

and

$$\vdash \Box^{-1}p \rightarrow \Box^{-1}\Box^{-1}p$$

but whereas I typically as an agent face alternative possible future courses of events, I have only one past. I own my past. I own up to my misdeeds, and take credit for what I have done well. Each agent has a history of what he has done, his aspirations, attempts, actions and achievements. So only one past. See Tree2.pdf on p.10 at end of this text for the previous choices of an undergraduate before he came to Oxford. As time progresses, and various choices are made, the unchosen alternatives drop off like branches from a growing trunk. (This explains why we express counter-factual hypotheticals by various uses of past tenses.)

The modal logic of $\Box^{-1}$ and $\Diamond^{-1}$ will be S4-ish, but not just the same as that of $\Box$ and $\Diamond$. Prior characterizes it by the law of Trichotomy, involving two events, p and q, and using his P for 'it was sometime the case that':

$$\vdash (Pp \wedge Pq) \rightarrow ((p \wedge Pq) \vee (Pp \wedge Pq) \vee (Pp \wedge q))$$

;
but it is better with inverse modal operators,

$$\Diamond\Diamond^{-1}p \rightarrow (\Diamond p \vee p \vee \Diamond^{-1}p)$$

.

This secures that there is only one past, which as of now cannot be other than it is. If we understand this as being unalterable now, we can view time modally as a passage from future possibility through present actuality to past unalterability.

> Time is the passage from Possibility through Actuality to Unalterability.

One difficulty should be noticed. In the development of modal logic as the natural enrichment of propositional calculus by one extra unary operator, arguments are adduced for having the thesis $\mathrm{D} \vdash \Box p \rightarrow \Diamond p$, but not the converse $D^* \vdash \Diamond p \rightarrow \Box p$; here, however, we do have $\vdash \Diamond^{-1}p \rightarrow \Box^{-1}p$: any event that is now a possible event in my past history must have already taken place, and now be necessarily an event in my past history. We might register the modal collapse of $\Box^{-1}$ and $\Diamond^{-1}$ into each other by writing both as $\bigcirc$, but in practice we have little occasion to, and so do not.

The argument that the past is different from the future because its accessibility relation is linear is not watertight. It has been assumed, but not established, that the accessibility for the future is not also linear; but this has been denied, often on scientific grounds, which will have to be considered in due course. So far as our ordinary concept of time is concerned, a non-branching future not only goes against our experience of making choices, but undermines the unique centrality of the present. In the tree model, although there are many nodes, each one of which could be, or could have been, a present, there is only one marked out by the structure of the tree as the actual present. The topmost—or last—node on the trunk, at which the first branches diverge, is picked out by the tree as *the* present, and contrariwise, every node defines a unique tree, showing what was already the case at that juncture, and what possibilities were open then. In a linear representation of the course of events there is no preferred node. Each could be picked out as the actual present, with as much justice as any other. Similarly, if there were branching towards the past, and we had not a tree, but a thicket, no node would be distinguishable as the present. All would be on the same footing, each as undistinguished as the others. Would this matter? In addition to our general intuition that

[2] As we have noted $\Box^{-1}$ and $\Diamond^{-1}$ will differ from $\Box$ and $\Diamond$ only in modal logics where the accessibility relation is not symmetric, that is, modal logics which do not have the Browerian thesis $\vdash \Diamond\Box p \rightarrow p$. If **B** is added to **S4**, it becomes **S5**, so it is reasonable to suppose that **S4**-ish logics do not have **B** as a thesis.

the present *is* different from the past and the future, we sense that it is peculiarly real: witness the fact that when we are telling fairy stories, we start by saying "Once upon a time . . ."; by disconnecting the time we are speaking of from the time at which we are speaking, we sever the link between the words we are enunciating and the world around us as we speak. A further witness is the reassurance we feel on learning that time is continuous, and that "there is no chink between today and tomorrow". In establishing the continuity of time, we establish the unvarying presence of the present, thus always providing time with a present anchor in reality.[3]

Although time, as we experience it, is tensed, the tensed view of time is under attack. The attack is partly philosophical, partly based on modern physics. Plato is against tense.[4] He is against self generally, having concluded that πλεονεξία (*pleonexia*), (more-for-me-ism) is the root of all evil, and that the ideal society is a self-less one, in which the words 'me' and 'mine' have no application. But tenses are covertly egocentric: the present is the time at which I am speaking; the past is the time before that at which I am speaking; the future is the time after that at which I am speaking. So they are under the same condemnation as the self.

It is tempting to see Plato's position as the converse of Aristotle's and Augustine's. They shrink the present interval until there is nothing left but an instant: Plato expands the present interval to encompass the whole of time. There is, indeed, a suggestion of this in Plato's rather lordly (μεγαλοπρέπεια *megaloprepeia*) dismissal of human concerns with human life-times,[5] there is also an argument from the mind's ability to project itself from the actual present to any other time. Any time is a potential now, and the philosopher, being able to project himself into any time, is therefore a spectator of all time. The real world for Plato is the static world of forms, which are timeless, impersonal, and not located in space. Modern scientific articles are imbued with the same spirit, being written in the impersonal passive voice, and seeking to establish omnitemporal universal truths. So too is Bernard Williams' "absolute conception of reality"[6] Reality is what there anyway, independently of when it is considered, or from what standpoint, or by whom.

Purely philosophical attacks on the tensed view of time have been strongly reinforced by physics. In Newtonian Mechanics and Electromagnetism there is temporal parameter, but it has no preferred direction, and no natural origin. We can work out the trajectory of a cricket ball given its initial conditions, but we can equally well regard them as final conditions, and work out the trajectory going backwards in time. Similarly in Electromagnetic problems, we simply discard some solutions—with advanced potentials—which would be perfectly valid if the future and past were interchanged. The TCP (Time Charge Parity) theorem expresses a deep symmetry which suggests that an interchange of past and future would be no more significant that one of positive and negative charge, or of clockwise and counter-clockwise rotation.

In Thermodynamics the direction of time is fixed, but there is, again, no natural origin. Past and future cannot be interchanged, but there is no indication within Thermodynamics of where the boundary between them is to be found.

These worries may be summarily dismissed with the observation that the theories in question are only theories explaining a limited range of phenomena. They are, so to speak, spectacles with which to view the motion of material objects, the propagation of electromagnetic waves, and the passage of heat. If I am working out the trajectories of cricket balls or the orbits of planets, I employ Newtonian Mechanics, but not if I am concerned with steam engines of refrigerators; the very fact that time has a fixed direction in Thermodynamics, but not in Newtonian Mechanics or Electromagnetism, argues against our taking too seriously its absence in the latter two theories. Newton knew that Newtonian Mechanics did not pick out a natural origin, but had arguments to show that it was still an intelligible question, and thought that perhaps it should be taken to be the centre of gravity of the solar system. Although there was nothing in the theory to pick out any one point rather than any other as the natural origin of the whole universe, extraneous conditions might well tell in favour of some particular point.

These general attacks are fairly easily countered. But the Special Theory supports more detailed, and more serious, challenges to the tensed view of time. Minkowski famously announced

[3] See above, The Ever-Present Present.

[4] *Timaeus* 37e.

[5] *Republic* VI, 486a8

[6] Bernard Williams, *Descartes*, Harmondsworth 1978, pp.64-67.

> 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. [7]

Many understand this to mean that time is just a fourth dimension in spacetime, completely on a par with the other three space-like dimensions, and so having no specifically temporal properties, such as tense.

Minkowski's spacetime also lends strong support to the picture of a "block universe", and suggests that the future is already in existence, just waiting to occur. We are to picture world-lines in Minkowski spacetime as timelessly existing and ourselves as going along a world-line encountering our pre-determined future as it takes place—in Weyl's words

> The objective world simply *is*, it does not *happen*. Only to the gaze of my consciousness, crawling upward along the lifeline of my body, does a section of this world come to life as a fleeting image in space which continually changes in time.[8]

But, still, this is only a picture. Although Minkowski spacetime, a four-dimensional manifold with Lorentz signature, seems more integrated and solid than a Cartesian product of a three-dimensional space with a one-dimensional time, exactly the same picture can be imagined if we think of a world-line in Newtonian space-and-time. In either case, we are offered a way of looking at the world, which may be useful for some purposes, but are nothing more than pictures. Both are available, both misleading, both non-obligatory.

Much more important than the picture is the integration itself, and the fact that whereas temporal duration was an invariant quantity under the Galilean transformations, it is not under the Lorentz transformations, which preserves only spacetime separations, but not either spatial or temporal separations separately. Mathematicians are tempted to assimilate timelike to spacelike directions and separations, arguing that they can transform Minkowski spacetime into a simple four-space by setting $ict = x_4$. But that is not a transformation of no consequence; a transformation that converts simple exponential functions into periodic ones is clearly a non-trivial one. But although Minkowski spacetime can be described as a four-dimensional manifold, its metric and topology are radically unlike those of a Euclidean four-space. The Lorentz signature $(+\,+\,+-)$ marks a fundamental difference between timelike directions and timelike separations on the one hand and spacelike directions and spacelike separations on the other.

The attack on time seems more telling if, instead of Minkowski's spacetime approach, we adopt Einstein's original one in terms of inertial frames of reference. Simultaneity is always relative to some frame of reference. If we change the frame of reference, we change the events to be reckoned simultaneous. Putnam, Rietdijk and Lango have argued for a timeless view of time, because of inconsistencies in our ordinary concept of simultaneity, and hence of there being no absolute distinction between present, past and future.[9] If we consider two observers in two inertial frames of reference moving with a uniform velocity with respect to each other, they will have different lines of simultaneity, and an event that is future to one will be past with respect to the other. So, it seems, we are forced to concede that there can be no inherent characteristic distinguishing the future from the present or the past, and that they are differentiated by nothing inherent but only their relation to particular observers; and from this it is a natural step to think of spacetime as a timeless entity, in which all events, present past and future, already in some sense exist; and to think of the apparent passage of time as nothing real, but only our becoming aware of what is already there, waiting for its moment of disclosure to us, in the way that Weyl suggests.

There is clearly something wrong with the argument. It depends on a confusion between two-termed and three-termed relations. It assumes that simultaneity is a two-termed relation, whereas in point of fact simultaneity is a three-termed relation, and we always have to ask "simultaneous with respect to what frame of reference?". Simultaneity with respect to a given frame of reference *is* an

[7] H.Minkowski, "Space and Time", An Address delivered at the 80th Assembly of German Natural Scientists and Physicians, at Cologne, 21 September, 1908; reprinted in A.Sommerfeld, ed., *The Principle of Relativity*, New York, 1923, p.75

[8] H.Weyl, *Philosophy of Mathematics and Natural Science*, Princeton, 1949, p.116.

[9] H.Putnam, "Time and Physical Geometry", *Journal of Philosophy*, 64, 1967, pp. 240-247; reprinted in H.Putnam, *Mathematics, Matter and Method. Philosophical Papers*, I, Cambridge, 1979, pp.198-205; C.W.Rietdijk, "A Rigorous Proof of Determinism Derived from the Special Theory of Relativity", *Philosophy of Science, 33*, 1966, 341-344, and "Special Relativity and Determinism", *Philosophy of Science*, 43, 1976, pp. 598-609; John W. Lango, "The logic of simultaneity", *Journal of Philosophy*, **66**, 1969, pp.340-350.

equivalence relation, so that if one event is simultaneous with another and that other is simultaneous with a third, then the first is simultaneous with the third. But simultaneity with respect to *different* inertial frames of reference is not an equivalence relation at all.

That argument of Putnam, Rietdijk and Lango fails: no event in the past of an observer can also be simultaneous with his Now; their argument depends on a simple equivocation in the use of the term 'simultaneous'. But still, it may be objected, there is an inconsistent ascription of dates, without appeal to lines of simultaneity. The ascription of futurity, presentness, or pastness is, therefore purely relative, and indicates no real property of the event. But that argument also fails. The lines of simultaneity for a given frame of reference do not determine what is currently going on at distant places, but only what dates should be ascribed to them in order to make electromagnetic phenomena coherent. As far as electromagnetic phenomena are concerned, we have no means of telling exactly when a distant event—an event in the"Absolutely Elsewhere and Anywhen"—takes place; but for any given frame of reference, IF we ascribe the same date to all events on a particular line of simultaneity, then the laws of electromagnetism apply neatly and yield harmonious results. So far as the Special Theory goes, simultaneity is a rather superficial and frame-dependent property, which we find useful for assigning dates to different events in different places, but which is not of fundamental importance in accounting for the propagation of causal influence. The ascription of presentness, pastness, or futurity, to events outside the light cone is nominal rather than real, and has no bearing on their real temporal status. Inside the light cone, however, there is a real difference between future events in the future light cone, present events at the vertex of the light cone, and past events in the past light cone. Whereas Minkowski gives us a uniform spacetime, albeit with an unusual topology, Einstein gives us a whole lot of tensed spacetimes, each with its own origin and own temporal directedness. But though they are different, they are similar none the less. Not only is the spacetime separation the same in all of them, but the laws of electromagnetism (Maxwell's equations), turn out to be similar, having the same form if we translate the spatial distances and the temporal durations in one cone into the corresponding spatial distances and the temporal durations in another. by means of the Lorentz transformations. The Lorentz transformations transforms the coordinates for dates and positions, and hence also durations and distances, in one cone (or "frame of reference" as physicists usually call them) into the coordinates for dates and positions, and hence also durations and distances, in another, depending on its relative position and velocity. Whereas the sameness of spatiotemporal separation is termed **in**variance, the similarity of form and interrelation is termed **co**variance. Thus spatiotemporal separation is **invariant** under the Lorentz transformations, while Maxwell's equations are **covariant** under the Lorentz transformations.

Covariance under the Lorentz transformations is like conjugation in ordinary grammar. We conjugate to transform an utterance spoken at one time by one person into what would be appropriate to be uttered at another time by another person. If I, John, tell you today that I am mending the car, you can state the same fact tomorrow by saying that John was mending the car yesterday. By conjugating the relevant verbs appropriately, different people can say the same thing at different times, much as by using the Lorentz transformations the same natural laws can be expressed in different inertial frames of reference, differently located and moving at different velocities relative to one another. In particular, the transformation of coordinates makes it possible in one frame of reference to work out whether those in another place events in that other's future, present, or past. It is not the case that invariant magnitudes are the only entities that, being frame-independent, are objective: covariant equations, expressed in terms of coordinates, which, though frame-dependent, are dependent in a systematic way, can claim to be objective too, on account of their underlying similarity of form. Whereas Minkowski's spacetime picture suggests a context-free, tenseless, impersonal view of reality, the picture of frame-dependent light cones allows the possibility of a more contextual account, in which tenses can be accommodated.

But that is not the end of the argument. If we ascribe a difference of modal status to what is present or past from what is future, it will be independent of our ascriptions of dates in some arbitrarily chosen frame of reference. Any God's-eye view of what is really fixed and unalterable as opposed to what is still open and indeterminate must impose a privileged frame of reference that is contrary to Einstein's principle that there are no privileged observers and no privileged frames of reference.

Once again, however, we point out that Einstein propounded his Special Theory in the context of electrodynamics. So long as we confine our attention to electrodynamics, we have good reason for adopting the Lorentz transformations as our way of correlating positions and dates in different inertial frames of reference, and for regarding each inertial frame of reference on a par with every other one. But it does not follow that that is the way we must ascribe positions and dates to distant

events, and that no other ascription could be correct, or that there can be no privileged frames of reference in some other science, such as cosmology.[10]

Cosmologists seldom agree, and though there are some who hold that there is a world-wide cosmic time, it is not an assured result of an established science, that can be called upon to refute Einstein. But quantum mechanics can. Although Einstein did not hold with a dice-playing God, and argued that our present quantum mechanics was merely a statistical condensation of an underlying determinist theory, the arguments of Bell and of Kochen and Specker, and the experiments of Aspect, have made it all but impossible to hold any "hidden variable" theory. We have to accept quantum mechanics as it is, and acknowledge that it is substantially correct and not likely to be augmented or amended in any significant way. It is indeed difficult to make sense of it, but it is natural to try and interpret it realistically, and to construe the collapse of the wave packet as a real event in which the many possible *eigen*-vectors, with their associated *eigen*-values, give way to a single *eigen*-vector with one definite *eigen*-value. If this is so, there is a definite moment of truth when possibilities become definitely true or definitely false. There is a fact of the matter, quite independent of whether we know it or not, and of how and when we know it. Knowledge may be unable to travel faster than the speed of light, but reality does not have to travel at all. Galaxies may be thousands of light-years away, and we shall be able to assign a date to a particular collapse only thousands of years after the event, and our assignment may well depend on an idiosyncratic choice of frame of reference, but nonetheless there will have been a definite moment at which the event occurred quite independent of any frame of reference. There is a world-wide tide of actualisation—collapse into *eigen*-ness—constituting a preferred foliation by hyper-surfaces (not necessarily flat) of co-presentness sweeping through the universe: a tide which determines an absolute present. In this, quantum mechanics goes beyond anything that thermodynamics and cosmology suggest, which, although witnessing to there being a definite directedness in time, do not pick out any particular time as pre-eminently real—the moment of truth when possibilities become actual or else fade away. Quantum mechanics, however, does. Although we still do not understand it, and its interpretation is still much disputed, it now appears to be irremediably probabilistic, and not only insists on the arrow being kept in time, but distinguishes a world-wide present as the boundary separating an unalterable past from a possible future not yet actualised.

[10] For further discussion of these arguments, see Howard Stein, "On Einstein-Minkowski space-time", *Journal of Philosophy*, **65**, 1968, pp.5-23; and 'A note on time and Relativity Theory", *Journal of Philosophy*, **67**, 1970, pp.289-294. See also M.Capek, *The Philosophical Impact of Contemporary Physics*, Princeton UP, 1961; and "Time in Relativity Theory: Arguments for a Philosophy of Becoming" in J.T.Fraser, *The Voices of Time*, London, 1968; O.Costa de Beauregard, "Time in Relativity Theory: Arguments for a Philosophy of Being" in J.T.Fraser, *The Voices of Time*, London, 1968; R.Sorabji, *Necessity, Cause and Blame*, London, 1980, pp.114-119; R.Torretti, *Relativity and Geometry*, Oxford, 1983, pp.249-251.