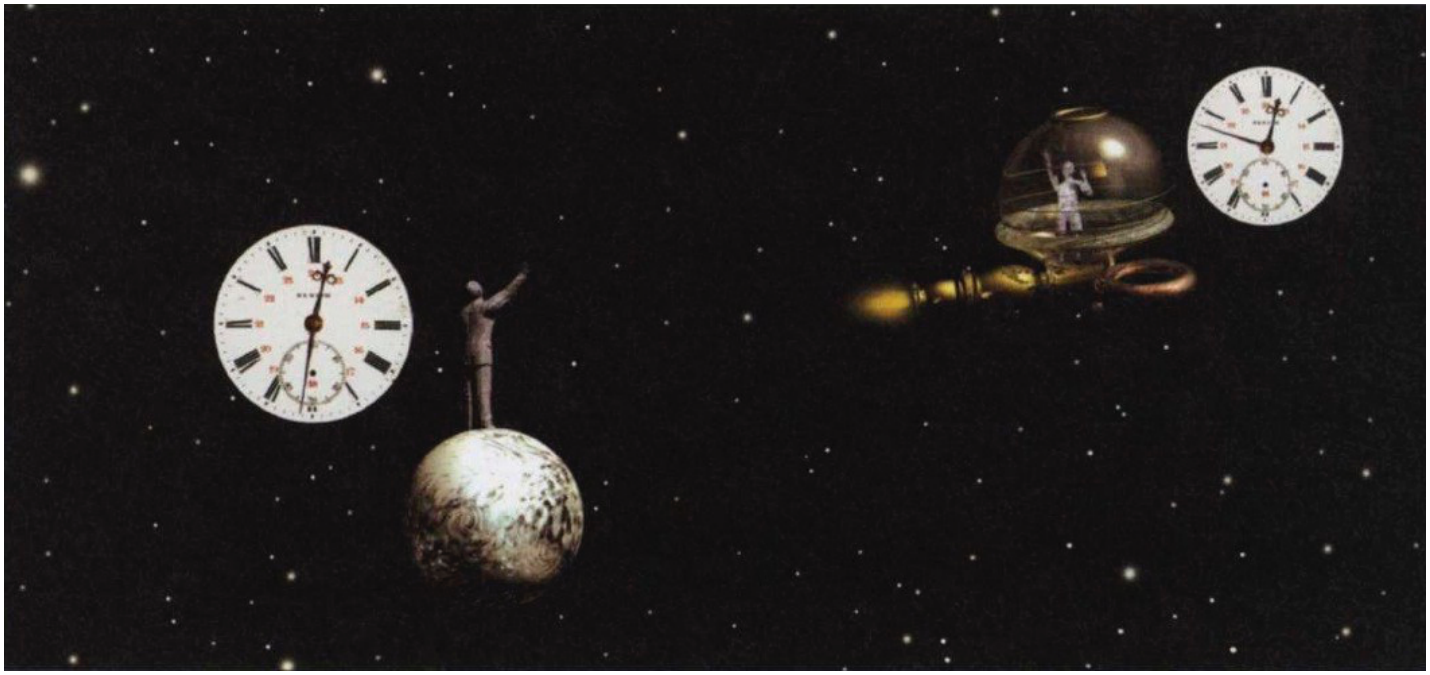
In light of the theory of Special Relativity is a Passage of Time and the argument of the Presentist untenable?



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Abstract

In light of the Special Theory of Relativity and the Minkowski creation of 'spacetime', the universe is taken to be a four-dimensional entity which postulates bodies as existing within a temporally extended reality. The Special Theory of Relativity's implications liken the nature of the universe to a 'block' within which all events coexist equally in spacetime. Such a view strikes against the very essence of presentism, which holds that all that exists is the instantaneous state of objects in the present moment. With respect to the present moment, events have a clear division into the past or future, however such regions do not exist in reality and the universe is a three-dimensional entity. The consequences of a four-dimensional universe are disturbing to say the least for our everyday human experience, with once objective facts about reality becoming dependent upon an observer's relative motion and the debate over the extent of true free will in a Block Universe. This paper will look at arguments which seek to rescue the presentist view in light of Special Relativity so such four-dimensionalist implications do not have to be accepted. Two approaches will be considered. The first accepts that presentism is incompatible with Special Relativity, and seeks to show that the theory is ultimately false. The second holds that it is the Block Universe interpretation of Special Relativity that is wrong, and a version of presentism can be reconciled with Special Relativity. The paper will expound and critically examine both of these approaches to review whether the case for the three-dimensionalist and a fundamental passage of time can be made.

Introduction: Thoughts on Time and Motivations for Presentism

'To us believing physicists the distinction between past, present and future has only the significance of a stubborn illusion.' Einstein

The presentism vs. eternalism debate has been anticipated by earlier thoughts regarding the nature time, predating the Ancient Greek Philosophers, entering the realm of Philosophy of Physics in the debate between Newton and Leibniz over the absolute or relative character of time and transitioning into modern day philosophy with McTaggart's (1908) A vs. B theory of time. This paper will examine the impact that Einstein's Theory of Special Relativity (SR) has had on our understanding of time and whether, as a result of the theory, we are compelled to accept eternalism.

According to the traditional presentist view, events can be unambiguously classified as past, present or future depending on their relation with the present moment. The universe is three dimensional and not four dimensional, with all that exists in reality being the spatially extended set

of objects in the present instant. ‘If the world is three-dimensional it exists only at one moment of time and *visa versa*’ (Petkov 2005 p.1). The pervasive passage of time, alongside an open future and decided past, is a fundamental part of our human experience and allows us to construct a framework within which to understand and characterise reality. It provides us with a background upon which we can conduct scientific enquiry and it is the ontological openness of the future that makes free will, in its fullest sense, possible.

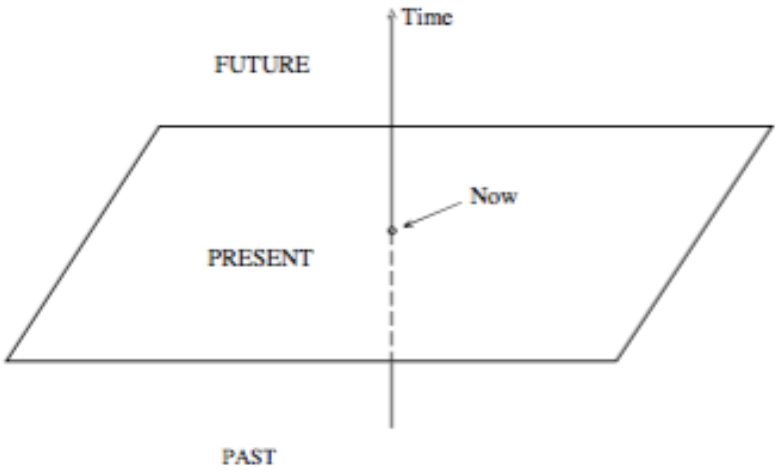

Fig 1. Taken from Petkov (2005). An illustration of the presentist view - the universe is three-dimensional it is only the present moment ‘now’ that exists.

The theory of relativity and its popular interpretation of a four-dimensional universe rejects the existence of an absolute passage of time and implies eternalism over presentism. The popular Minkowski interpretation of the theory denies the existence of a privileged time and proposes that the universe is four-dimensional continuum within which all events can be assigned coordinates x,y,z,t. As a result, the universe can be viewed as a ‘block’ in which all events exist on an ontologically equal footing as proposed by eternalism, with time as much a dimension of the universe as the three of space.

The three dimensional vs. four dimensional universe debate can be reformulated in terms of eventism versus objectism as described by Maxwell. ‘According to objectism, the world is three dimensional and not four dimensional. The basic entities are spread out in space, but not in time.’ (Maxwell 1985 p.29) Objectism postulates a fundamental difference between space and time where ‘spatial relations are between objects’ and ‘temporal relations are between *facts-about*-objects.’ (1985 p.29) Eventism, is the opposing view that reflects the premises of the Block Universe, in which ‘the world *is* spread out in both space and time. The basic entities are four-

dimensional events, not three-dimensional objects' and spacetime is an entity in reality rather than a tool to depict facts regarding the history of objects.

Maxwell (1985 p.25) also defines two affiliated types of probabilism, '*ontological probabilism*' which views the future as open and having numerous 'ontologically real alternative possibilities' and '*predictive probabilism*' which 'asserts the future is in reality fixed and decided' even though what exists at one instant plus the basic laws makes only probabilistic predictions about future states of affairs. Predictive probabilism views the world as spread out in four-dimensional Minkowskian space-time whilst ontological probabilism views the future as having alternative possibilities (which do not pre-exist in reality) and as time progresses these possibilities cease to exist as the present state is realised.

The traditional presentist, objectist and ontological probabilistic views are all inherently incompatible with SR, given its four-dimensional Minkowski interpretation, as they require a universal distinction between events which have already been realised and those which are yet to be, by a cosmic 'now'. These views allow for free will in its most 'full-blooded' (Maxwell 1993 p.344) form where our actions are not fixed or in any way pre-determined as they are in the theories of the eternalist, eventist or predictive probabilist. Although slightly tongue in cheek, Yourgrau condemns the four-dimensional Block Universe in 'A World Without Time' (2005 p.123) when declaring 'one need only recognise the befuddlement that would ensue if one were to try and act on the assumption that today's breakfast is no more actual than yesterday's or tomorrow's, that the future, like the present, has already arrived… Should I still be wondering what to order for breakfast yesterday, as I am for tomorrow, or should I cancel both orders because the meals have already arrived?'

It is obvious, I hope, why one would want to seek arguments to rescue the presentist view, in light of such implications of the theory. In this paper I will present arguments which seek to counteract the views of the eternalist, which are supported by the Minkowski interpretation of SR and analyse whether the presentist view can be regarded as tenable. The implications of SR profoundly impact issues at the very heart of what it means to be human and our understanding of reality. As such, philosophical considerations of the theory's implications are not only imperative but natural and it is through this synthesis of disciplines that we can obtain a deeper insight into the nature of time in our universe.

Literature Review: The Special Theory of Relativity

'*The objective world simply is, it does not happen. Only to the gaze of my consciousness, crawling upward alone the life line of my body, does a section of this world come to life as a fleeting image in space which continuously changes in time.' (*Weyl 1949 p.116)

Einstein's relativity drastically changed popular scientific thought on the nature of time. Prior to relativity the best physical theories were Newton's classical mechanics and Maxwell's electrodynamics, in which time was regarded as absolute and 'independent of the position and the condition of motion of the body of reference.' (Einstein, 1988, p.30) Einstein's motivations for SR came from the apparent inconsistency between the principle of relativity and law of propagation of light. The principle of relativity states that if any frame of reference K is Galilean, any frame of reference K' which is related to K by a uniform motion of translation, will also be Galilean. Relative to K' the laws of motion should hold exactly as they do relative to K. Therefore, 'natural phenomena run their course with respect to K' according to exactly the same general laws as with respect to K.' (Einstein, 1988, p.13) The embodiment of the idea of an absolute reference frame would be a frame K_0 in which the 'natural laws are capable of being formulated in a particularly *simple manner*' and hence we should 'be justified in calling this system "absolutely at rest" and all other Galilean frames K "in motion".' (Einstein, 1988 p.14) However, according to the principle of relativity each frame has as good a claim to be at rest as any other.

This leads to the apparent incompatibility of the law of light propagation with the principle of relativity. The velocity of the speed of light c was a fixed constant as a consequence of Maxwell's equations, hence it must have the same velocity in all Galilean reference frames, as again, 'natural phenomena run their course with respect to K' according to exactly the same general laws as with respect to K'. (Einstein, 1988, p.13) However the original Galilean transformations propose the addition of velocities, such that the overall velocity of light would be dependent on the velocity of its source (regardless of whether the light relative to the source remained fixed at c). It was by uniting these two seemingly incompatible principles that Einstein arrived at his Special Theory of Relativity.

To go from one reference frame to another 'relations must be so chosen that the law of the transmission of light *in vacuo* is satisfied for one and the same ray of light with respect to K and K'.' (Einstein, 1988, p.32) Such relations are named Lorentz transformations. Through these Einstein shed the assumption of the absolute character of time and distance (and consequently any case for an ether) with the phenomena of time dilation and length contraction. It is unclear whether Einstein knew about the null result of Michelson Morley experiment in detecting the ether or whether he just assumed the ether did not exist when deriving his Lorentz transformations of SR. Regardless, 'the role of the Michelson experiment in the genesis of Einstein's theory appears to

have been so small and indirect that one may speculate that it would have made no difference to Einstein's work if the experiment had never been made at all.' (Holton, 1969, p.195)

$$x' = \gamma(x-vt) \quad y'=y \quad z'=z \quad t' = \gamma\left(t-\frac{vx}{c^2}\right) \quad \gamma=\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$

The Lorentz transformations: Where x',y',z',t' are taken as the coordinates in the K' frame, and x,y,z,t the coordinates in the K frame. The axes of K and K' are parallel and K' moves along the x-axis of K

The principle of relativity and Lorentz transformations abolish the notion of an absolute time through the phenomenon of the *relativity of simultaneity.* This phenomenon is the key step in overthrowing the concept of an absolute time and presentism. Presentism requires that any two spatially separated events are unambiguously either simultaneous, or that one is objectively earlier than the other. Whilst the relativity of simultaneity states that two events could be said to be simultaneous for one observer and have a temporal separation as measured by another observer. From the Lorentz transformations above we can see that δt between two events in one system of coordinates can be zero (the events are simultaneous) whilst in another set of coordinates, δt' can assume any positive value (the events are non-simultaneous). Einstein therefore concludes, 'every reference-body has its own particular time; unless we are told the reference-body to which the statement of time refers, there is no meaning in a statement of the time of an event.' (Einstein, 1988, p.26)

Einstein's original ideas in his paper 'On the Electrodynamics of Moving Bodies' (1905) were inherently related to measurements, the workings of rods and clocks. This is evident when he states in chapter XII 'Rods and Clocks in Motion' 'it is quite clear that we must be able to learn something about the physical behaviour of measuring rods and clocks from the equations of transformation, for the magnitudes x,y,z,t are **nothing more nor less than the results of measurements obtainable by means of measuring-rods and clocks.**' (1988 p.36) As Maxwell (1985 p.30) highlights, 'Einstein originally formulated special relativity in such a way that objectism is presupposed' with reference frames being characterised in terms of rods and clocks, persisting objects' a view compatible with a three-dimensional universe.

However, in the Minkowskian view put forward in 1908, the world of physical phenomena exist in four-dimensions, in a structure known as 'space-time'. Four numbers can be ascribed to every event, 'three space co-ordinates x,y,z and a time co-ordinate, the time value t' (Einstein, 1988 p. 55) and objects trace out curves, or 'worldlines' over time (Einstein, 1988 p.56). Minkowski's radical contribution was his reformulation of the time coordinate t to ict. Through this mathematical

manipulation, the time coordinate is given the same 'role' or ontology as the three space coordinates, it is due to this fact that, according to the theory of relativity, the 'time' x_4 enters into natural laws in the same form as the space co-ordinates x_1, x_2, x_3.

$$x_1=x \quad x_2=y \quad x_3=z \quad x_4=ict$$

A strong similarity with Euclidean three-dimensional geometry is then created. Distances in these four-dimensions, known as spacetime intervals, are always preserved regardless of the observer's chosen frame of reference, as conventional distances on rigid bodies are in three dimensional Euclidian geometry. This relationship is given by:

$$\partial s^2 = \partial x_1^2 + \partial x_2^2 + \partial x_3^2 + \partial x_4^2 = \partial x'^2_1 + \partial x'^2_2 + \partial x'^2_3 + \partial x'^2_4$$

Where x',y',z',t represent a different frame of reference from x,y,z,t.

Minkowski then uses the four-dimensional geometry, replacing t with ict, to create a relativistic temporal structure through the construction of a light cone. The past light cone with $t < 0$ and future light cone with $t > 0$.

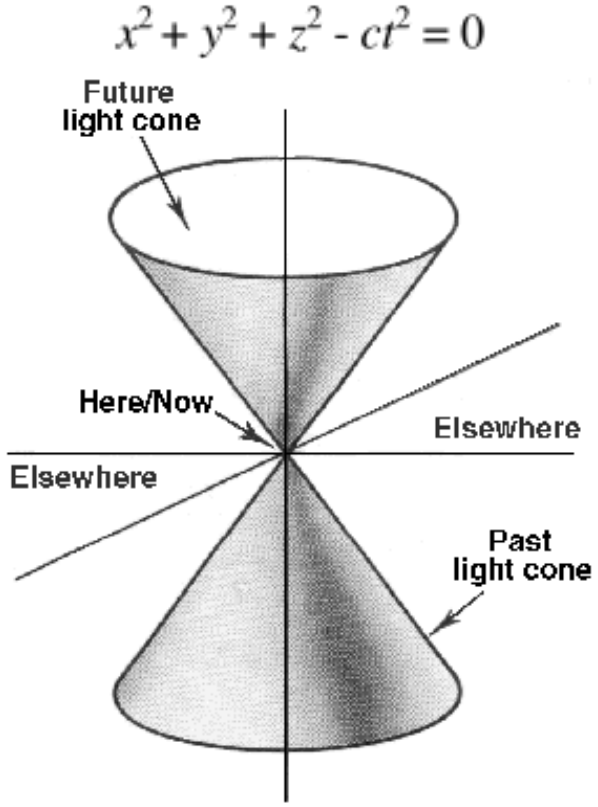

Fig 3. A Light Cone, given by the equation stated above, suppressed in one spatial dimension.

Given an event a, existing at Here-Now and the classification of another event b is as follows:

1. b is in the past light cone of a (b < a), b is fixed and realised
   the vector from a to b is past-oriented timelike vector
2. b is in the future light cone of a (a < b), b is not realised
   the vector from a to b is a future-oriented timelike vector

Temporal structure therefore clearly still exists for time-like separated events. Events do not have an exact and absolute ontological separation of space and time but overall causality is preserved and observer independent temporal facts about reality *can* be given across all reference frames. Such a structure cannot be held if a and b are space-like separated events.

3. b is in the casual elsewhere of a that is, b lies outside both the past and future light cones of a and whether b is realised or not cannot be objectively determined
   the vector from a to b is space-like vector

In this case the temporal ordering of spatially separated events is purely dependent on the observer's frame of references and any t coordinate values can be given such that one may be earlier than, simultaneous with, or later than, the other. 'Any world-point between the front and back cones of O can be arranged by means of the system of reference so as to be simultaneous with O, but also just as well so as to be earlier than O or later than O.' (Minkowski 1908 p.84) This lack of agreement in simultaneity is precisely what undermines the presentist due to their requirement for an unambiguous cosmic now.

Minkowski's 1908 address opens with the famous remark '*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, 1952, p.75) However despite giving aesthetic reasoning in favour of spacetime, 'it is only in four dimensions that the relations here taken under consideration reveal their inner being in full simplicity, and that on a three dimensional space forced upon us *a priori* they cast only a very complicated projection' (Minkowski, 1952, p.90) he does not give an explicit argument that SR *must* be or *can only be* interpreted in the spacetime way. And thus, Minkowski does not himself explicitly formulate the argument that SR implies presentism is false. There exists a big difference between a formulation being a possibility and an obligatory stance given the theory, and it seems Minkowski's account four-dimensionalist spacetime comes away as merely a very attractive and convincing way of interpreting SR, which upholds the nature of the theory and is one a mathematician or theoretical physicist would find hard to resist.

Whilst the Minkowski interpretation of SR proposes that the universe should be seen as a four-dimensional entity, within which all spacetime events exist equally, philosophers Rietdijk and

Putnam attempt to clarify explicitly why the ‘Block Universe’ is *the* logical conclusion from the principles of the theory. Their arguments use spacetime diagrams to compare events across different observer reference frames, from which ‘a proof is given that there does not exist an event, that is not already in the past for some possible distant observer at the moment that the latter is "now" for us.’ (Rietdijk 1966 p.1). As such, the papers seek to show the Minkowskian view of the universe stands true, given SR. A similar approach employing spacetime diagrams is presented below. However Gödel, significantly earlier in 1949, gives an argument for the four-dimensional universe as a result of SR and later this is supported in GR with his introduction of Closed Timelike Curves. This argument is presented in a subsequent section.

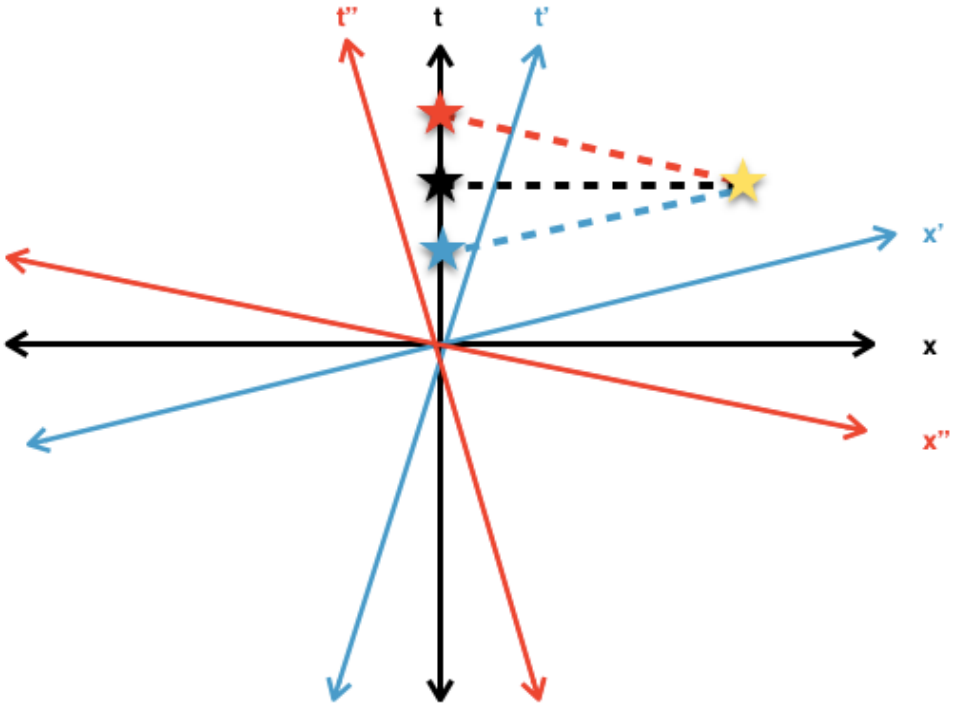

Fig 2. Spacetime Diagram of three inertial observers X,X’,X” and their respective axes and planes of simultaneity (indicated by dashed lines).

The diagram is a spacetime visualisation of three observers: X, X’, X”. Each has their own time and space axis and planes of simultaneity represented (dashed lines). If two events lie along a certain observer’s plane of simultaneity, they are considered simultaneous in that observer’s reference frame. The present for an observer in the framework of relativity is taken here to be comprised of events considered simultaneous in their frame of reference, an adaptation known as relativised presentism. The observer X, whose frame is considered at rest, is shown in black. For X the common event, indicated by the yellow star (*) is simultaneous with black star event (B) at what X measures to be t=1. For observer X’, travelling at speed v relative to X, event * is simultaneous

with the blue star event (C). For observer X'', travelling at speed v in the *opposite* direction to X', event * is simultaneous with the red star event (A).

Comparing these on X's time axes we can see the C has a lower time coordinate value than B and hence can be said to be in the past for X when he is at t=1. A has a higher time coordinate than B and hence can be said to be in the future for X at t=1. At event * which is common to all observers, X is justified in saying B currently exists, X' is justified in saying C currently exists, X'' is justified in saying A currently exists. From this formulation, where all inertial frames are considered equivalent in their justification, all events can be said to be equally real.

It is logical to see how this set-up can be expanded to include all points in space and time, ultimately creating the idea of a Block Universe. If B and * were separated on an astronomical distance scale, the planes of simultaneity of X' and X'' that include * would extend their intersection with the t axis of X to higher and lower values of t. In theory, if B and * were separated far enough, the intersections would occur at $t = \infty$ and $t = -\infty$ for X. Moreover, if the speed of X' and X'' was comparable to the speed of the light, their corresponding axes relative to X would be appear much more condensed, (closer to the 45 degree line) with steeper planes of simultaneity again intersecting further back and forward on the t axis of X. Rietdijk (1966 p.343) on this argument states 'every event is pre-determined from time immemorial'. Moreover, according to Dainton (2001 p.9) 'If the block universe is true, the view that the future is open is wrong, for the future is just as real, solid and immutable as the past. How our lives will unfold from now until the moment of our death is already laid down…the choices that we will make are inscribed in the fabric of reality in precisely the same way as choices that we already have made.' I hope these unsettling quotes are convincing enough to remind the reader of the motivations to attempt to rescue the presentist view.

Arguments: Efforts to rescue Presentism

In the light of the theory of relativity there are two distinct approaches that can be taken in the attempt to rescue presentism. There are those that state presentism is not compatible with SR but hold that SR is ultimately false along with its eternalist implications. Arguments of this type that will be examined are; evidence from General Relativity (GR) for an absolute time and possibilities of unified theories of quantum gravity disproving eternalist claims. Secondly there are those that state presentism or at least a form of becoming can be compatible with relativity. They seek to do this by incorporating presentism into SR by various means. Either the four dimensional framework is unnecessary to explain physical phenomenon, as proposed by the Neo-Lorentzian interpretation, or the assumptions behind the Block Universe are wrong as put forward by Stein's 'point presentism' and Dingle's comments on time vs *the* time. Each of these arguments shall be presented and critically expounded. To begin with we shall look at possible evidence from GR for a preferred reference frame and hence absolute time.

1) Evidence from General Relativity for an Absolute Time

Special Relativity is, as its name indicates, special as it is only valid in inertial frames moving with constant velocity with respect to each other. GR, is the parent theory within which subsystems of flat space can be modelled by SR. Although in SR there are no frames of reference that can be considered privileged, in the general theory there are situations in which there may be. Such frames could then be coordinated so that they determine an absolute time, a 'cosmic time'. The problem faced by the presentist is a justification of on *what grounds* a metaphysically preferred reference frame can be chosen. Smolin claims this justification can be found on the astronomical scale as 'the universe is arranged in such a way that it picks out a preferred state of rest… the motions of galaxies pick out a preferred observer, hence a preferred state of rest at each point in space.' (Smolin 2014 p.166)

According to the mathematician logician Gödel, time could regain its objective existence on this astronomical state as 'the existence of matter, as well as the particular kind of curvature of space-time produced by it, largely destroy the equivalence of different observers and distinguish some of them conspicuously form the rest, namely those which follow in their notion of the mean motion of matter' (Gödel 1949, p.559) On the local scale we have no detection of this and the principles of SR apply with sufficient accuracy.

Cosmologists also look towards the distribution of Cosmic Microwave Background Radiation (CMBR) for search of a privileged reference frame. 'The cosmic microwave background radiation fills all of space and is remarkably isotropic for any observer at rest with respect to the expansion of space. The radiation background will be anisotropic for any observer in motion with respect to an observer whose spatial coordinates remain fixed. It therefore acts as a sort of aether, serving to distinguish physically a fundamental universal reference frame.' (Time and the Metaphysics of Relativity, Craig p.220) By an observer whose spatial coordinates remain fixed, it is meant an observer for whom the radiation is isotropic, and who thus may be regarded as motionless. Moreover, in models of GR there are seen to be preferred foliations of spacetime, preferred geometrical slicings. For example in Schwarzschild spacetime, one natural slicing gives a space whose geometric properties remain constant over time, whilst in the Robertson-Walker spacetime, 'one slicing gives spaces filled with homogenous matter distributions'. (Norton 2000 p. 6) According to Savitt (2000 p.S572) 'the presentist should throw in the towel with respect to SR, but need not admit defeat, for there is GR and beyond yet to be examined.'

Criticisms of an Absolute Time from General Relativity

There are criticisms over whether moving to the cosmos as a whole provides a sufficient basis for regarding one frame a privileged. Firstly, why exactly should a frame be privileged if it follows the mean motion of matter? Suppose there are N reference frames, in an otherwise empty space, all in relative motion, consisting of equally massive rods and clocks. If one of these frames is taken and progressively increased so its mass is far greater than the rest combined why should that make it in any sense privileged? Why should the contingent state of affairs, in this case the average local motion of matter, have consequences for the nature of basic physical laws in the universe? Furthermore, symmetry features inherent in SR face problems with this approach. SR states that if Frame 1 and 2 are inertially related, if F1 measures a contraction in F2 then F2 will measure that same contraction in F1. If F1 is then taking to be at rest with the mean motion of matter or the CMBR but these symmetry observations still hold, does this not suffice to refute the idea that F1 is somehow privileged within the framework of SR? Secondly, curved spacetime is required to reduce to flat Minkowski space on all local scales. Therefore as GR collapses in all cases to SR and seeing as SR, if interpreted in the Minkowskian sense, violates presentism locally should these problems not then automatically be retained when scaling up to the domain of GR? It seems the problems for the presentist from SR would continue to be relevant, as GR retains SR as a limiting case theory.

Thirdly it could be argued that, if anything, GR is more committed to the spacetime view than SR and the Minkowski interpretation becomes more solidified when moving to GR. Einstein needed the spacetime view in order to formulate GR and make sense of the curvature existing in space and time. Moreover in features of GR such as Black Holes, space and time intertwine at the horizon and beyond with once spacelike vectors becoming timelike in the formulation. However, the most devastating blow to the presentist from GR comes from Gödel's 1949 paper on the possibility of Closed Timelike Curves (CTCs) in the context of rotating universes. Gödel (1949 p. 560) states, 'there exist cosmological solutions of another kind than those known at present, to which the aforementioned procedure of defining an absolute time is not applicable, because the local times of the special observers used above *cannot be fitted together into one world time.'* In worlds such as these 'making a round trip in a rocket ship in a sufficiently wide curve, it is possible to travel into any region of the past, present and future and back again, exactly as it is possible in other worlds to travel to distant parts of space.' (Gödel, 1949 p.560) Although CTCs are features of unrealistic situations (i.e. rotating universes) and have not been proven to exist in our world nevertheless Gödel's findings still have implications for what GR says about our world. Even if CTCs only exist in universes different from ours they remain a feature of GR and therefore have implications for what GR says about the nature of our universe. CTCs as a feature of GR are inherently incompatible with presentism and heavily support the Block Universe. If the Block

Universe is supported in a possible universe predicted by GR, it is implied in all possible worlds in which GR holds. Changing the contingent states of affairs to which a theory apples does not change the theory and from these results it seems it must be concluded that GR also implies presentism is false.

2) The NeoLorentzian Approach: The Claim for a Metaphysically Preferred Reference Frame

Arguments of the second type shall now be turned to, those which propose that presentism or a notion of becoming is compatible with SR. The most popular of these being the Neo-Lorentzian (NL) interpretation of the theory most notably advocated by Craig (2001) in 'Time and the Metaphysics of Relativity.' Craig (2000 p.118) believes the Minkowski Interpretation (MI) is lacking explanation and 'the Neo-Lorentzian will charge that a perspectival, four-dimensional approach to relativistic phenomena has resulted in the neglect of the search for the dynamic causes of time dilation and length contact, a major oversight'. The NL interpretation puts forward a 3+1 dimensional ontology of the world with the existence of an absolute time and privileged frame of reference, relative to which all other frames are considered in motion. Length contraction and time dilation occur for events measured in frames in motion relative to the privileged rest frame. Comparatively, in the MI objects exist in four dimensions, such that they are temporally extended and proper time and length measurements vary between reference frames with each frame equally justifiable in their claim to being 'at rest'. Seeing as possible arguments for the existence of a privileged reference frame (hence an absolute time and rescue for the presentist) have been mentioned in this section of the paper, we will now examine the merits of the NL interpretation's explanation of the phenomenon of length contraction and time dilation against that of the MI.

In order to account for phenomena of length contraction, Lorentz and FitzGerald assumed 'that the motion of the body relative to the aether produces a contraction of the body in the direction of motion.' (Einstein, 1988, p.54) In this case the ether represents the privileged reference frame, which in turn would give an absolute time. Such postulations came in the wake of Michelson-Morley experiment which attempted to detect the relative motion of matter with respect to the ether by comparing the speed of light in perpendicular directions. The experiment was met with a null result and thus required explanation to account for the failure to detect motion through the ether. Lorentz and FitzGerald put forward the conjecture that rods in motion through the ether contracted in accordance with the Lorentz transformation along the line of motion, relative to the rest frame. Such contractions were motivated by the contraction of electrostatic fields in the direction of motion as discovered in 1888, though at the time there was no reason to presume the forces between matter molecules were of a similar nature. As such, the explanation of contraction phenomenon in the Neo-Lorentzian interpretation are largely regarded as ad-hoc.

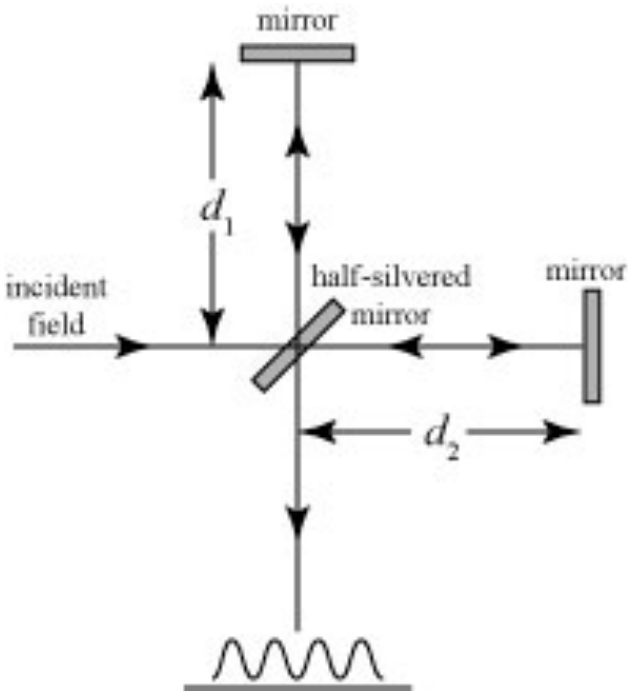

Fig 4. Set up of the Michelson-Morley experiment. Beams of light sent to a half mirror where they are split into perpendicular directions before being recombined to detect an inference pattern. If an interference pattern were present this would confirm the difference in the speed of light due to relative motion with the ether.

The crucial difference between this explanation and that from SR as put forward by Einstein (1988, p.53) is that, in relativity 'there is no such thing as a "specially favoured" coordinate system to occasion the introduction of the aether-idea…as the prime factor involved in this contraction we find is not the motion in itself, to which we cannot attach any meaning, but the motion with respect to the body of reference chosen in the particular case in point.' However in the NL interpretation the measured time and length are special in the rest frame K_0, these are the *true* proper values from which *all* other measurements are transformed. The Lorentz transformations form a group compatible with the principle of relativity which makes the existence of a privileged rest frame undetectable. The undetectable nature allows no for possible verification by experiment between the two interpretations.

The kinematic consequences of the theory can still be expressed in a 3D language and the 3D-er does nowhere state that the privileged planes of simultaneity should be distinguishable, hence the 4D-er cannot use this as an argument against their case. It is consented that 'the argument (for the MI) is not iron-clad and may still be outweighed by the needs of theology or quantum mechanics.' (Balashov, Janseen 2003 p.25) Due to the unobservable differences between NL and MI, the argument to favour the MI for its simplicity of explanation is nothing more, according to Earman (1989 p.48), than 'an objection based on Occam's razor.' Indeed, it could even be

suggested that if one is arguing on the grounds of simplicity the NL interpretation should be preferred to the MI, as the latter proposes the metaphysical existence of four-dimensions, which adds excessive ontological structure to a universe which could exist, in accordance with experimental proof, in three dimensions.

Criticisms of The NeoLorentzian Approach

In the Minkowski Interpretation, length contraction is a product of the four-dimensional geometry, shown by 'two observers who are in relative motion to one another and therefore use different sets of space-time axes and disagree about which cross-section of the 'world-tube' of a physical system gives the length of the system' (Balashov, Janssen 2003 p.10). The way in which the MI explains the physical phenomenon is seen as mathematically elegant, arising naturally as a by-product of the geometry of the spacetime. The Lorentz transformations are derived by Einstein directly following from the principle of relativity, light postulate and isotropy of space. The NL however is regarded as highly ad-hoc in comparison by Janssen as 'it is, in the final analysis, an unexplained coincidence that the laws effectively governing different sorts of matter all share the property of Lorentz invariance…In the space-time interpretation this coincidence is explained by tracing the Lorentz invariance of all these different laws to a common origin: the space-time structure posited in this interpretation.' (Balashov, Janssen 2003 p.24)

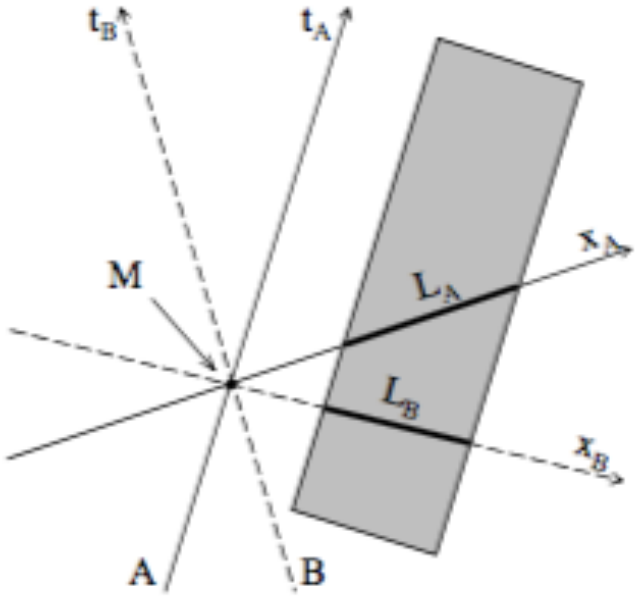

Fig 5. Taken from Petkov (2005) An illustration of the Minkowski interpretation of Length Contraction: The cross section L of a rod's worldtube as seen by two observers A and B, in relative motion.

It seems, that the NL interpretation cannot appeal to a hypothetical ether to provide explanations for the behaviour of rods and clocks in motion and do justice to the phenomenon successfully predicted by SR, namely symmetry. Given two rods, with one in relative motion to the other, which is considered stationary with the ether, how could the symmetrical effects of observed length contractions be explained when working from within each rod's reference frame. This seems fatal to the Neo-Lorentzian theory.

Moreover, the undetectable nature of the metaphysically privileged reference frame in the NL interpretation is a strength as well as a significant weakness. According to the distinguished philosopher of science Karl Popper, all scientific theories should be empirically falsifiable. Theories can never be proven, but they can be falsified. Sound scientific theories should allow experiments to analyse and make deductions on their strength and validity. Popper believes, if the results of the experiment go against the theory, one should refrain from manipulations that are ad hoc, which evade the contradictions by merely making them less falsifiable. This precise manoeuvre can be critiqued of the Lorentz-FitzGerald contractions following the Michelson-Morley experiment in the search for the ether.

Finally, if the Neo-Lorentzian theory invokes exactly the same Lorentzian transformations as the original interpretation, what function does the rest frame play at all? It is treated as all other inertial frames. As Savitt (2000 p.S570) duly notes 'this metaphysically distinguished present cannot, according to the relativity principle, be ascertained by any physical measurement or experiment. If the present is indeed so elusive, I find it difficult to imagine what aid or comfort it could be to a metaphysician.' Savitt (2000 p.S570) views the Neo-Lorentzian approach as merely 'a strategy for rejecting special relativity in favour of presentism rather than accommodating presentism in Minkowski spacetime' where the loss of a sound explanation of the physical phenomenon seems too high a price to pay for adding an undetectable rest frame to our ontology. To choose a metaphysically distinguished hyperplane to represent the present in this way is nothing more than 'inertial chauvinism'. (Savitt 2000 p.S570)

3) The Argument from the Anti-Realist regarding The Nature of Time

A different objection to the dismissal of an objective flow of time comes from the anti-realist. In SR from the relative *measurements* of time across different reference frames it is understood that time is relative *in reality*. However the anti-realist may argue that it is misguided to loose our belief in an absolute time as a result of the information we have obtained from our measurements alone. Such measurements may reflect our interpretation of time but not necessarily the way time really is. Dingle (1979) speaks of this differentiation and creates a distinction between what he calls *the* time, which is based on readings of measuring instruments in scientific enquiry (measured time) and experiential time itself (absolute time). When Minkowski famously 'let t denote time' Dingle

believes he falsely identified clock readings with the experience of time itself. This dramatically transformed Einstein's theory, which worked with *measurements* alone, postulating that relatively moving *clocks* work at different rates, to a theory which seemed extremely incomprehensible and characterised fantastical phenomenon like 'time-dilation' as fundamental aspects of nature. Descriptions of intuitive time, according to Dingle, must be metaphorical whilst our scientific measurements are restricted to dealing with the temporal coordinate of the theory t.

On what grounds *should* we believe that if our scientific theories are experimentally successful that they reflect 'truth'. Laudan (1981) in 'A Confutation of Convergent Realism' argues that the realist would like to say if a theory is successful it is approximately truth, however this is only an intuition and a connection between success and approximate truth must be argued for implicitly. 'The realist's *hunch* that increasing deep-structural fidelity must manifest itself pragmatically in the form of heightened experimental accuracy has yet to be made cogent.' (Laudan 1981 p.35) Therefore, according to the anti-realist why should our measurements of time, although accurate in representing the workings of clocks for relatively moving observers, necessarily reflect the true nature of reality. The instrumentalist approach instead would be to accept spacetime and four-dimensional geometry as a convenient device for predictive purposes, but not accept the existence of such an entity in reality. Similarly, Van Fraassen's constructive empiricism proposes that accepting the best scientific theory only requires believing that it is empirically adequate in describing the observable world, but it does not have to be believed to be truth simpliciter.

Criticisms of the Anti-Realist

The criticism of this time versus *the* time Dingle-type distinction can be summarised aptly by responses of the Realist. SR and GR are our best theories regarding the nature of time and thus we should take them and their implications seriously. The Realist would argue that if we do not take our successful theories to be approximately true and reflecting of the underlying nature of reality then the success of science becomes a miracle. (Putnam 1975)

It can also be argued that time is a human construct and thus all we postulate about the nature of time should be from our empirical deductions. Perhaps our ordinary experiences lead us to believe there exists a higher order time though there is not. Stein (1991 p.162) believes we have developed such illusionary intuitions of 'cosmic simultaneity' from our ordinary experiences in that 'the time that we experience as a specious present is in the exact sense already explained contemporaneous with events as far distant, spatially, as we ever normally have to do with at all.' Perhaps on distance scales as local as ours, at speeds far slower than the speed of light we share the experience of a common present, though this need not be the true nature of time.

4) An Alternative form of Presentism in the context of Relativity Theory

This argument seeks to reconcile a form of presentism with the Theory of Relativity. In the Rietdijk-Putnam style creation of the Block Universe we see two key assumptions. Firstly, the form presentism takes in a relativistic framework, which Hinchliff (1996 p.130) calls the 'relativised present'. 'In a relativistic setting, presentism is the view that the real events for an observer are the events simultaneous with the observer in the observer's frame of reference'. The second assumption is the principle of transitivity that is, if x is real for y, then y is real for x. Together these assumptions states that: if an event X is real for observer A (simultaneous according to A's reference frame), and observer A is real for us (simultaneous in our reference frame), then event X is real for us too (principle of transitivity). This then leads to the understanding that all events are equally real in the 4D universe. Hinchliff (1966 p.131) believes 'the assumption of relativised presentism is *one* proposal about what the doctrine of presentism is in a relativistic setting, but it is *not the only one*, or even the most plausible one.'

An alternative form comes from Stein who instead believes a theory known as 'point presentism' is the correct description of presentism within relativity. According to Stein, in the framework of relativity, the only meaning of the present is that assigned to a 'here-now', at a spacetime point and 'the only really simultaneous events are events which occur at the same place.' (Robb, 1921, p.13) The entity from which the distinction of what events are definite or indefinite is made from the perspective of the 'here-now' as we have seen above in the geometric properties of the light cone. Event A could be said to be in the future of event B if and only if it was in the future light cone of B. Event C could be deemed to be in the past of event B if and only if it was in the past light cone of B. This casual structure is consistent across observers. 'For an event - a spacetime point a, those events, and only those, that have already become real are those which occur at points in the topological closure of the past of a' (Stein 1968 p.14)

For Stein, a notion of passage is restored through the perspective of the 'here-now' alone and temporal relations between timelike separated events. Thus SR accommodates a new form of relativistic becoming. The view does away with the eternalist perspective whilst respecting 'the spatiotemporal symmetries of relativistic physics yet maintains there is more to time's passage than the block universe picture permits.'

Criticisms of An Alternative form of Presentism

In adopting 'point presentism' we seem to lose much of the meaning the traditional present once held. If the present is reduced to a 'here-now' and only the event at which the observer is located is regarded as present (hence real and determined) suggests a strange form of 'spatio-temporal solipsism'. It seems 'a little discomfiting to the presentist to restrict reality to just one point

of spacetime.' (Savitt 2000 p. S568) This is somewhat counteracted by the claim that 'each point of spacetime is present' (with respect to itself) so equivalence is preserved but if then 'no point of spacetime is metaphysically distinguished from any of the others with respect to presentness' (Savitt 2000 p. S568) it seems the point-presentist argument completely disintegrates and reduces to eternalism once more. If all points are special, none are. By adopting 'point-presentism' it could be argued that we manage to reconcile a form of relativistic becoming with SR but in doing so do we take away all the full-bloodedness from traditional presentist's argument, such that it is unrecognisable as a presentist theory. There is no longer a universal present moment or a clear division between a fixed past and open future. As Savitt (2000 p.S569) summarises, 'point-presentism' may 'be *called* presentism, but it fails to capture the fundamental metaphysical intuitions underlying presentism.' The block universe interpretation of SR which relies on the two assumptions previously stated may be seen to be flawed in assuming these are the only options but is this enough to rescue the presentist? At most the foundations of the eternalist may be seen to be weakened but this does not mean we can say the presentist it correct. To do so we need to find a way to reconciling our metaphysical intuitions about the present with the physical theories.

5) The Advancement of Scientific Theories and Probabilistic Quantum Gravity

The final argument believes presentism is irreconcilable with relativity theory but that Special and General Relativity are ultimately false. Newtonian theory and classical mechanics were once considered the most accurate theories of the physical world. However the theory of electromagnetism developed by James Clerk Maxwell had inconsistencies with Newtonian theory, namely over the speed of light. As such, SR was developed, highlighting Newtonian mechanics as only an approximation, valid in systems travelling much slower than the speed of light - a limiting case earlier theory. SR itself is nowhere perfectly instantiated and emerges as an approximation in systems of flat space from GR. What can be said of GR? A theory which could make more accurate predictions over a larger range of phenomenon, let it be called T, could falsify GR. As Nicholas Maxwell (2006 p.4) explains 'almost always in the history of physics, when a new theory, T, unifies two predecessor theories, T1 and T2, T reveals that T1 and T2 are strictly speaking false.' T in this case is likely to come in the form of a theory of quantum gravity, due to GR's inherent conflict with quantum theories. However, SR and GR being false does not rescue the presentist as their eternalist implications must too be false in light of the advanced T.

On what grounds can we currently seek falsification of the spacetime view and verification of the presentist? To do this we look towards Probabilism. Ontological probabilism as defined by Maxwell (1985) views the future as open and having numerous 'ontologically real alternative possibilities'. This probabilistic view is inherently incompatible with SR and GR due to its

requirement for a universal present to distinguish between events that have already been realised and those which are yet to be. GR is a deterministic theory and if the laws of the universe were found to be probabilistic in this way, so that the future *is* open with many alternative possibilities, it would render SR and GR false and propose the need for a universal present. Of course, we cannot *assume* the laws are probabilistic in this way, but the fact that they could be and the fact that GR is likely to be falsified means we should not condemn all presentist theories which conflict with SR's implications.

Orthodox quantum theory states quantum mechanics is deterministic with the evolution of the wave function governed via Schrödinger's time-dependent equation. However when measurements are made in quantum mechanics, probabilistic events occur. As N. Maxwell (2015 p.7) states, 'failure to solve the quantum wave/particle problem also leads to the failure of orthodox quantum theory to answer unambiguously whether the quantum domain is deterministic or probabilistic.' However, probabilistic changes of the quantum state imply instantaneous transitions, such as the phenomena of wave packet collapse and these probabilistic changes conflict directly with the relativity of simultaneity. Such a collapse would only be regarded instantaneous in one reference frame, that which is at rest with the wave function, and hence would pick out a unique, privileged frame whilst SR demands all inertial frames be seen as equivalent. If instantaneous probabilistic collapses of quantum states really do occur in nature - as they may do, for all we know at present - this would not only falsify deterministic GR. It would also provide grounds for picking out privileged reference frames - those with respect to which probabilistic collapses are instantaneous.

Maxwell (2015 p.10) suggests such 'probabilistic collapses of quantum states are *all that there is in the constitution of things* that picks out 'the reference frame at rest' and thus 'the associated cosmic now'. This opposes the previous view that a privileged frame could be found in the analysis of universal matter distribution. Maxwell explains SR and GR could be good approximations in the deterministic evolution of macro states whilst having no way of determining the hyperplanes that constitute the rest frame. Yet the 'quantum probabilistic transitions determine, physically, that frame uniquely at rest', the 'cosmic wide now''. (Maxwell, 2015, p.11) Furthermore Stephen Hawking speculates that CTCs, which appear as certain solutions to GR and imply the Block-like Universe, may be done away with by quantum gravity in a conjecture labelled the chronology protection conjecture.

The view of Scientific Realists is that theories advance to a truth and maintain their predecessors as limiting case approximations. As seen in the History of Science, theories have continually advanced and 'just as Newton corrects Kepler and Galileo, and Einstein corrects Newton, so future theories will no doubt correct Einstein.' (Maxwell 1985, p.29) A unification of GR and QM could produce a more advanced theory T. Moreover, if QM is interpreted probabilistically, T could take the form of probabilistic quantum gravity, whose implications rescue an absolute frame

of reference, in accordance with instantaneous probabilistic transitions, and thus act as a rescue for the presentist.

Criticisms of Probabilistic Quantum Gravity rescuing Presentism

Although QM may provide grounds to rescue presentism, it is still very much a speculative matter. The nature of wave function collapse is a highly controversial issue, with many physicists advocating deterministic interpretations of quantum mechanics such as the Bohm or Many Worlds Interpretation in which the wave function goes off to realise all possibilities in alternate, ever branching, universes. A unified theory of GR and QM therefore need not be probabilistic but preserve determinism. Furthermore, if the wave function itself does not correspond to anything physical in reality and is merely understood in instrumentalist terms, then the instantaneous collapses could be made reconcilable with Relativity Theory, preserving equivalence across all inertial reference frames. However, the evidence of theories and future physics whose implications contradict the eternalist implications of SR and GR gives substantial hope to the presentist. Moreover, given our understanding that GR has its limitations and is not a final theory, alongside evidence from the History of Science, this argument seems enough to save presentism from untenability.

Discussion: Review of efforts to rescue Presentism

To conclude, let the arguments presented be reviewed and their relative merits to rescue presentism be assessed. The arguments from General Relativity and Cosmology present us with possible evidence for a preferred reference frame and consequently an absolute time through cosmological analysis; such as the analysis of Cosmic Microwave Background Radiation and the geometry of certain spacetime metrics. However, this evidence is not yet beyond the level of speculation and ultimately SR remains a limiting case theory of GR Thereby, if presentism is violated in local systems by SR it remains to be a problem for the presentist universally as all systems in GR reduce to locally flat Minkowski space in which SR holds. Moreover there is evidence for the spacetime view being further entrenched in GR. To conclude, it does not seem the argument from General Relativity is enough to save the presentist.

Secondly, the NeoLorentzian approach states that presentism can be reconciled with Special Relativity if a 3+1 dimensional ontology is accepted, instead of 4 dimensions, alongside the existence of an undetectable metaphysically privileged frame. It could be said that the NL interpretation adds less ontological structure to reality and hence should be preferred on the grounds of Occam's razor however the interpretation has many downfalls. The justification for the choice of a metaphysically preferred frame is not given and remains substantially ad-hoc, whilst its

undetectability leads to severe criticism over the consequential lack of falsifiability of the theory, a criterion often deemed necessary for a successful scientific theory. Furthermore, the theory lacks the ability to coherently explain the physical phenomenon of the symmetry of length contractions and time dilations as postulated by SR. If events at rest with respect to a metaphysically preferred frame equally undergo contractions from the point of view of an inertially moving reference frame then what is the role or significance of the preferred frame at all and what hope could the presentist possibly draw from it's existence? To conclude the NeoLorentzian interpretation seems to provide no rescue for the presentist when compared to the Minkowski interpretation which seems a much more natural exposition of the theory itself.

Thirdly, we review the anti-realist regarding the nature of time. The anti-realist argues that although our measurements of time, in accordance with the postulates of the theory, suggest the nature of time is relative in reality this should not mean it is so in reality. The anti-realist may argue in instrumentalist terms that spacetime and four-dimensional geometry are excellent tools for helping us probe the phenomenon and drawing predictions but this should not mean these entities exist in reality or are a direct reflection on the nature of reality. Secondly, why *should* we presume our measurements have a grip on the workings of reality or that our successful theories reflect an approximate 'truth' - as such a connection cannot be proved necessary. The reply to these criticisms are merely the standard arguments of the realist; SR and GR are our best theories of time and thus we should take their findings and implications seriously, else we make the success of science an apparent miracle. The realist, anti-realist debate has been an a central debate in the history of philosophy of science for centuries, so to draw on one side of this argument (which cannot be said to have ever clearly defeated the other) is not sufficient to rescue the present - it becomes a matter of philosophical inclination.

Fourthly, there is the argument for an alternative form of presentism in the context of Relativity Theory. Taking the Minkowski interpretation of the theory and its assumptions we reach the conclusion of the Block Universe. Such a construct requires the doctrine of the presentist in the relativistic framework to be that of the 'relativised present' whereby all the events that are viewed as real by an observer as those that are regarded to be simultaneous with him in his rest frame. Stein presents an alternate form of presentism in the context of relativity known as 'point presentism'. This doctrine restores a form of temporal becoming in the framework of SR and thus postulates substantially more than the eternalist and his Block Universe. However in reducing the present to a 'here-now', the position drastically detracts from the 'full-bloodedness' of presentism as much of the meaning of the traditional present is lost. There is no longer a cosmic 'now' or universal present moment distinguishing between a fixed past and open future. The 'here-now' present moment can be criticised in its reduction to resembling solipsism. Therefore, although perhaps the closest so far in restoring some sense of temporal passage, this argument is not a sufficient rescue for the presentist.

Finally, we examine the argument from the advancement of scientific theories and the possibility of a future unified theory taking the form of probabilistic quantum gravity. As seen from the history of science, theories are repeatedly replaced by successor theories which most often retain their predecessors as limiting cases whilst increasing their predictive powers to wider subsystems of nature. As Newtonian Mechanics and SR were ultimately proved to be false by their successor theories so likely too will GR. In fact it is already evident that GR is not a final theory due to its inherent incompatibilities with the Quantum domain. QM possesses several phenomenon which could be described probabilistically, such as instantaneous wave packet collapse and if such phenomenon were verified they could provide evidence for a rest frame and cosmic wide now. However, probabilistic interpretations and the nature of their corresponding phenomenon are still extremely speculative. If QM could provide evidence that the laws of nature were fundamentally probabilistic and a unifying theory took the form of probabilistic quantum gravity, eternalism could be said to be refuted and presentism would triumph. Such theories remain very hypothetical but the hope (and the unknown) of future physics provides us good enough reason to believe that presentism should not be untenable given relativity theory. Until we achieve a unified theory, from which we can confidently judge the nature of time, the four-dimensional view may remain viable however one day the three-dimensional view may become equally as so. Science and our understanding of the universe undergoes continual progression and as such we would do ourselves an injustice to rule out theories, such as presentism, from our unfinished standpoint.

Conclusions: Time and scientific enquiry

Recapping initial thoughts, the pervasive passage of time, with an open future and decided past, is a fundamental part of our human experience. It is from such a pervasive passage we are able to construct a framework to better understand and characterise reality and the ontological openness of the future is what grants us our free will. To do away with this presentist idea of time would severely undermine our perception of the world and place in it.

When interpreting the meaning of scientific theories we must take care that we consider the nature of the disciplines involved. An interdisciplinarity synthesis is extremely important when physical or mathematical theories seek to draw ontological conclusions as the level of our empirical enquiry are severely limited when compared to the vast scales of the cosmos. Moreover, as history has shown physical theories are progressively replaced by those more and more advanced and philosophy must continue to act as a check that we are not over-interpreting our findings when we use the success of our theories to postulate truths about the nature of reality.

Philosophy strives for a clarity, an attention to conceptual weak points in theories that is sometimes lost in the calculations of the physically inclined. For Physics to be able to advance and marry theories that seem presently incompatible, i.e. GR and QM, in order to arrive at a theory

which will bring us closer to understanding the nature of time in our universe, we require philosophy to seek the conceptual incompatibilities between the physical theories to guide us. It is precisely this synthesis of thought that led Einstein, when reconciling the apparent incompatibilities between the principle of relativity and law of the propagation of light to arrive at his Theory of Relativity in the first place.

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