# Retroactive Event Determination and Its Relativistic Roots

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**Abstract.** Quantum theory limits what we are allowed to say about the "true" state of a quantum system if that system is unobserved. But special relativity relies fundamentally on a universal assumption about what a light particle is doing at *ALL* times, regardless of being observed (namely, traveling at speed c relative to any inertial observer). This constitutes a fundamental conceptual gap between the theories. In resolving this impasse we show that the state of a light particle (and hence space and time) is not objective or continuous. Time dilation and length contraction become infinite for a photon, so light has no "experience" of event separation in space or time ($\Delta t' = 0$, $\Delta x' = 0$). The principle of simultaneity is applied between an inertial observer and a light particle, such that the relative speed of the two systems is c, and gamma = infinite/undefined. Although light experiences no separation between events, the Lorentz transform $\Delta t' = \gamma\ (\Delta t - \Delta Lv/c^2)$ implies that *the inertial observer* experiences a separation between those same events of exactly $\Delta t = \Delta L/c$, a light-like separation. In other words, although light does not "register" time or space itself, light will always be measured by an inertial observer at a position and time exactly *as if* it had travelled at speed c continuously through the intervening medium. This fits nicely within the limitations set by quantum mechanics. This result is connected with previous work on retroactive event determination, suggesting the ubiquitous existence of "synchronicity".

**Keywords:** Special Relativity, General Relativity, Quantum Mechanics, Retrocausation, Synchronicity, Simultaneity, Presentism, Eternalism, Possibilism

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## THE CONCEPTUAL GAP BETWEEN SR AND QM

One of the central mysteries of quantum theory involves the inability to make a definite statement about the state of a thing about which we have incomplete information. The form reality takes, it seems, is highly dependent on the information we have about reality. Therefore, the information we have is more than a simple epistemological measure, it is a determination about the ontology of reality, as evidenced by Wheeler's statement of "It from bit." According to Wheeler, "all things physical are information-theoretic in origin." [1] Special relativity (SR), which was fully developed before any significant progress in modern quantum theory was even begun, does not incorporate this central mystery. In fact, SR relies on a fundamental assumption that light travels at a speed 'c' relative to all inertial observers at all times, regardless of whether it is being observed or is interacting with anything. Quantum mechanics (QM) continues to experimentally reaffirm its principles of observation based states, so it is critical that we reevaluate the assumption stated above for SR.

According to QM, it is not valid to say that we can know the objective state of a photon at all times. The only properties we can make a definitive statement about are those we have measured. SR could instead say that every time we measure a photon we measure it travelling at the speed of light but that in between measurements such statements are meaningless. In this case, the postulates of SR would still hold, but they would not violate the principles of QM. This is essentially the program undertaken here.

In the section Derivation and Interpretation of the Asynchronicity Principle, I step through the basic math of SR and use the results to examine some standard interpretations of the theory. The interpretation of light's movement through space-time as observer-dependent is suggested. I rename the principle of simultaneity (in SR) to the principle of asynchronicity (for reasons that will become apparent), and then show that this principle is the reason why an inertial observer will always measure a photon travelling in light-like intervals, even if one cannot say what it is doing between measurements.

In Connection to Retroactive Event Determination, it is shown that the asynchronicity principle aligns with a principle proposed in [2] called retroactive event determination (RED). Through this connection it becomes apparent that special relativity and quantum theory both point to a common underlying physics and metaphysics.

In the section Implications, I examine the implications these principles may have on our understanding of space, time, and reality. The possibility of the ubiquitous existence of synchronicity is discussed.

In the section Philosophy: Ontology and Context within the Literature, I review the ideas in this paper with respect to the standard philosophies available in the literature. We will see that the assumption stated above (the travel of light through space at speed c as an objective fact) implies a belief in an objective reality. We will examine this belief in light of the evidence of SR, QM, general relativity and various other principles, using the previous work of a variety of authors.

In Closing, my conclusion will be that an observer will always measure light in a place and time *as if* it had smoothly traversed the intervening space. Yet we cannot say that it has objective smooth motion through space-time. Rather, it exists primarily as a superposition of possibilities which will only take a definite state relative to a specific observer when measured.

## DERIVATION AND INTERPRETATION OF THE ASYNCHRONICITY PRINCIPLE

### Renaming the Simultaneity Principle

After originally deducing the principles of length contraction and time dilation, Einstein realized that they created contradictions. The relativistic principle states that all inertial reference frames must experience the same laws of physics, and the properties of the events they observe must be logically consistent when compared. Suppose, for instance, that I am still and you are moving. The time dilation effect would indicate that your clock is ticking slowly because you are moving. But who's to say that I'm not the one moving, rather than you? From your perspective, I am the one who is moving, and it is my clock that is ticking slowly. These two versions of the same reality did not seem to match, and Einstein's principle of simultaneity was the breakthrough step that resolved this paradox. [3]

Though time may be ticking at different paces for different reference frames, spatially separate events are kept in agreement between reference frames by the *offset* of time (asynchronization) as a function of position. This is not limited to a particular arrangement of circumstances, such as simultaneous events. Rather, any pair of reference frames in motion relative to one another will experience offsets in the time measurements of events, based on the events' relative position and speed.

The Lorentz transform shows that an observer will find that time slows down (is dilated) and is offset (is asynchronized) for any moving objects in his surrounding environment. The principle of simultaneity states that simultaneity is a relative property of two events. If two spatially separated events are simultaneous from one inertial reference frame, they will *not* appear simultaneous for other inertial reference frames that are in relative motion with the first frame. The main effect of this principle is that spatially separated events which in one frame of reference are simultaneous will not be simultaneous from *any other* reference frame in relative motion. In fact, the two events do not need to be simultaneous to begin with. The point of the principle of simultaneity is simply to show that the temporal spacing between events changes when we change reference frames, and simultaneous events are just a special circumstance of this principle. In renaming this property to the 'asynchronicity principle', I am trying to emphasize the actual behavior of what Einstein discovered: the temporal spacing of events in one reference frame is different from the temporal spacing of the same events according to an inertial frame in relative motion. This principle is not focused especially on simultaneous events, but rather on the asynchronization of all events in space-time relative to different inertial observers. The name change is particularly helpful in presenting the concepts in this paper, because it is the time offset (or asynchronization) between all spatially separated events which will be our main focus here.

In general, we can describe the principle of asynchronicity by saying "the event which is behind in motion is ahead in time." For readers unfamiliar with the principle of simultaneity in special relativity, an online search for the terms "simultaneity principle special relativity" returns many sites with standard explanations.

## Physics Derivation

The starting point here is straightforward and should generate no controversy. It has been noted by others before that the principles of time dilation and length contraction, when taken to their extreme asymptotic limits, result in indefinable spatial and temporal intervals. For instance, Savitt [4] says "Godfrey-Smith's suggestion seems to rest on the idea that events on the past light cone of E have a lightlike separation from E and hence the space-time interval from E to (say) E' (on the past light cone of E) is 0." A reference to Godfrey-Smith's work [5] is in the references section.

So it is understood that the Lorentz transformation yields a time and space interval of zero between any two lightlike related events in this extreme situation. Here we will make this explicit, beginning with the Lorentz transformation, equation 1.

$$t' = \gamma\left(T - \frac{Lv}{c^2}\right) \tag{1}$$

The Lorentz transformation describes the time interval t' between two events as measured by a moving observer O' relative to the stationary observer O, who observes a time interval of T and a spatial interval of L between the same two events. Imagine two events A and B that are separated (in observer O reference frame) by distance L and happen a time T apart. Also, imagine the special case where a secondary observer O' is moving at exactly the speed v = L / T. In this case, it could easily be arranged so that event A would happen right when O' passed the location of A, and B happened right when O' passed the location of B. In other words, this is a special case of the Lorentz transformation where the events being observed are initiated by or synchronized with the moving frame itself. In such a case, the relative speed of the two frames is exactly equal to the separation of the events, v = L / T, and the result for t' is given in equation 2.

$$t' = \gamma\left(T - \frac{vTv}{c^2}\right) = \frac{1}{\sqrt{1-\beta^2}} T(1-\beta^2) = T\sqrt{1-\beta^2}, \qquad \beta \equiv \frac{v}{c} \tag{2}$$

Now imagine a simple experiment that measures the speed of light (granted, this is not technically simple, but it is conceptually simple). We measure the time it takes for light to cross the room. Of course, we cannot simultaneously know the emission time and the absorption time, because any signals used to do so would travel less than or equal to light speed. Yet regardless of this, we can infer from our devices the amount of time taken to get from point A to point B. If point A and B are L meters apart, then the time taken would be T = L / c.

This example fits the criteria of the above scenario, since the events being measured are the locations of the moving frame (the light) itself. We can also check the validity of the assumption that the Lorentz equation still holds even when v = c by evaluating the behavior in the limit as v approaches c. This is a perfectly well-behaved limit (simply a semi-circle), as seen in Fig. 1, graphing $(1-\beta^2)^{1/2}$ vs. β. In the limit as β approaches unity, the time registered on the photon's clock goes to zero.

If the laboratory observer (who measures L and T in the lab frame) were able to see the passage of time for the photon in this interval, it would be perfectly still, as shown in equation 3. This is the passage of time as registered by light's own clock. Since the relative speed of the two systems is equal to c (so β = 1), we find that t' = 0.

$$t' = T\sqrt{1-\beta^2} = 0, \qquad \beta = 1 \tag{3}$$

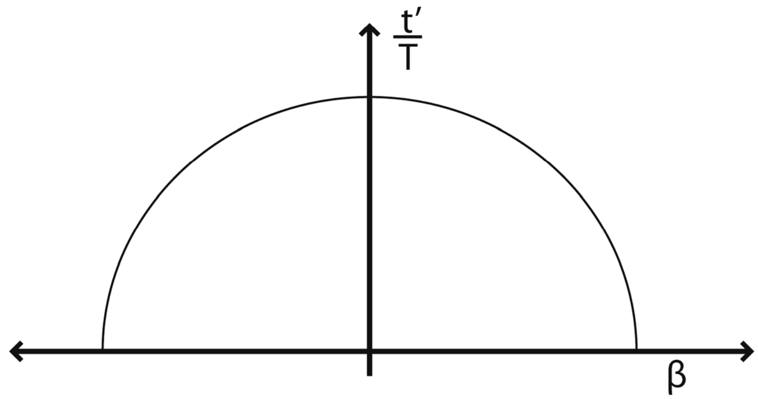


**FIGURE 1. Relationship between t' and T as a function of β for the given scenario.**

The reader may be concerned that one is not able to apply such concepts of time and space to light itself, since it is by definition not in an inertial frame. Whereas we can't speak of light in anthropomorphic terms, as if it can 'see', we should agree that the manner in which light 'registers' time events must be a valid concept to explore, since it clearly interacts with the physical environment in concrete and measurable ways. The relationship between the 'time measured by an observer in the laboratory frame' and 'how light itself is registering the same two events' is a perfectly valid comparison. The idea that it is valid to apply the Lorentz transformation to light even though it does not (by definition) exist in an inertial reference frame is taken up in the next section.

Note that this does *not* mean we can consider light as having a valid inertial reference frame (it doesn't). It simply gives us the ability to discuss how the principles of special relativity apply to light itself, and what implications they have for the nature of light.

Though this result is probably uncontroversial from a mathematical perspective, its physical interpretation is far from clear. To my knowledge, a deeper analysis of its interpretation has been neglected. Clearly, by definition from the SR light postulate, light cannot exist in an inertial reference frame. Therefore, the extreme limit of the Lorentz transformation would appear to be a result that does not represent anything physically meaningful (i.e. there are never two inertial reference frames that have a relative velocity of c). It is a central aim of this paper to provide a coherent interpretation of this limit, and understand its implications. Specifically, I am proposing that the particular case of the Lorentz transformation where the relative speed between frames is c applies to any interaction between an inertial observer and a photon.

## How Light Registers the Universe

In order to understand better what light is and how it travels, we have essentially asked the question "How does light itself *register* events?" The phrase "how light registers the environment" is used to mean something similar to "how light sees the environment," but without the suggestion that light can actually have a sensible inertial perspective. We should be able to agree that light "interacts with" its environment, as is clear from the obvious fact that we inertial observers are ourselves reciprocally interacting with the light. In other words, we know that light interacts with the world since we experience those interactions from our own inertial perspectives. We shouldn't say "How much time would light measure between event A and event B?" because the anthropomorphism of 'measure' causes problems. So we rely on the word "register" to convey this notion of interaction without any implication of light being conscious or aware of the space-time intervals it is registering. The previous analysis of time dilation and space contraction leads to the conclusion that light cannot register any distance or time separations between events.

So our question becomes "what would happen to light (if anything) *between* two such interactions?" This is a perfectly valid question. For instance, if an inertial observer were to witness a series of interactions and say that between two interactions A and C an intermediary interaction B occurs that is distinguishable from A and C, then it seems at first that the light must also be registering these events separately and at separate times. We would then say that light does register the passage of time. If, on the other hand, light cannot distinguish between the various interactions it has, then we should say that light cannot register the passage of time, or the distinct space-time events A, B and C. In this case, although the inertial observer measures distinct space-time coordinates for the interactions with the light, these coordinates would be meaningless to the light itself.

dWe have pointed out that Einstein's original question led him to the specific conclusion that as an observer approaches light-speed, the observer measures time passing asymptotically more and more slowly for the objects passing by around him (the quantity $\gamma$ in equation (1) and equation (2) grows without bound). We then extended this argument to light itself, saying that light would register no passage of time (or spatial interval) between events. Finally, then, this seems to imply that light cannot distinguish between any events in space-time. As might be guessed, we are beginning to consider a notion of light as omnipresent. Although it is very difficult for us inertial observers (who exist within physical space-time) to imagine this, it is very easy to describe this exact behavior within physics using the Fourier transformations, as will be taken up in a future paper.

In addition, as one approaches the speed of light, the order of measured events becomes exceedingly jumbled, due to the principle of asynchronicity. The Minkowski diagrams in Fig. 2 provide a graphical illustration of this. We conclude again that for light itself all distinctions of order and measurements based on time lose their meaning.

We might be tempted to conclude that a light beam, from its own "perspective", travels through a paralyzed world, a world frozen at a single instance of time. However, there is a problem with this conclusion. A light beam clearly does *not* travel through a frozen world. The world is in one state at the moment when a light beam registers event A at point $(x, t)_A$, and the world is in a different state when the light beam reaches event B at point $(x, t)_B$. So the beam, even from its own perspective, obviously does not "travel from A to B while the world remains frozen." Moreover,

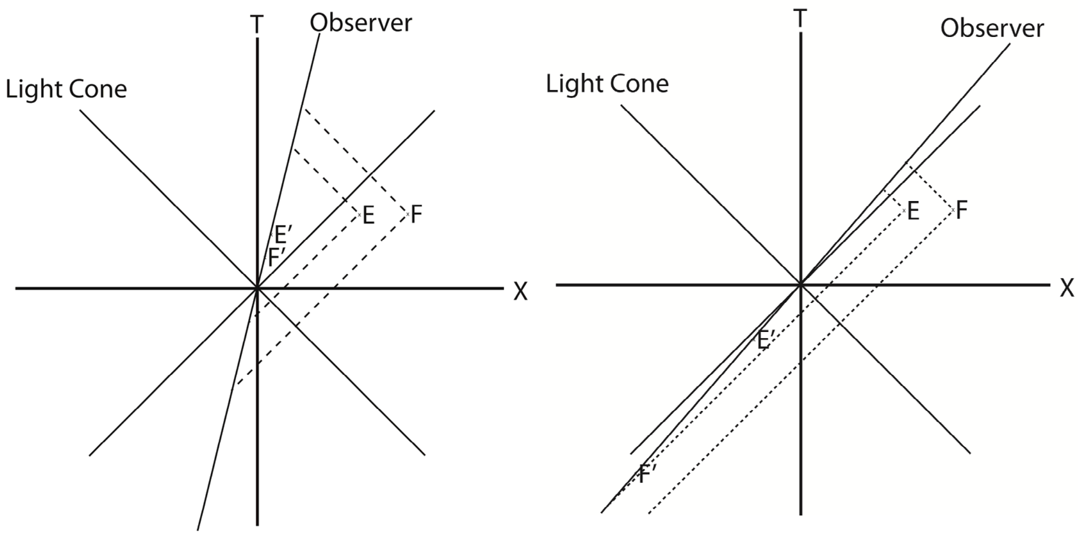


**FIGURE 2: Minkowski diagrams showing two events which are simultaneous from the rest frame, appearing more and more asynchronized as the inertial observer approaches the speed of light.**

Lorentz contraction implies that all distances become completely contracted at light speed. Thus, it cannot be the case that a light beam, from its own perspective, travels from A to B while A and B remain frozen, because from the beam's perspective, there is no distance between A and B over which travel.

The problem may lie instead with trying to ascribe motion to the light beam in the first place. We could say instead that the light beam, from its own perspective, must somehow exist simultaneously at every location and moment in its journey. If a light beam leaves location A at $t_A$ and reaches location B at $t_B$ from our inertial observer's perspective, then from its own 'perspective', both space-time coordinates are co-present. The A in which the light is present is the A of $t_A$, and the B in which it is present is the B of $t_B$. Somehow the light must register both these events as one thing, with no spatial or temporal separation.

So how can a beam of light possibly coexist at both points? Quantum mechanics dictates to us that the future is open (not predetermined), so we see that the light cannot travel directly from event A to event B while the events remain frozen, for this would imply that event B was predetermined at the time event A happened, from the light's perspective. All outcomes of the experiment would be predetermined. Yet we have seen that the two events are not distinguishable according to light. If light is to be able to coexist at two events which are separate from the point of view of an inertial observer and *not predetermined in outcome*, we could consider that event B is just one of many possible outcomes. In such a model, light does not travel through a frozen determinate world, but rather through a 'frozen' indeterminate world of possibilities.

Thus, if we consider the wave function of the light to be a collection of possible outcomes in an extra (fifth) dimension, as discussed in [2], then all of these possible outcomes can coexist (as information only) in the form of wave functions, without predetermining the outcome of a situation. The possible futures already exist, but the actual (physical) future will only unfold at the space-time coordinates that it is observed.

The reader may wonder what is actually new in this proposal, for this is essentially the way we currently understand the quantum mechanical wave function. The aim of this section, and really this paper overall, is to provide an overall context that is capable of knitting together the various current understandings from disparate fields into one cohesive whole.

The delayed choice 2-slit experiment can help illuminate these concepts. First, we note that the particle of light is not in a definite state until it is observed. Before the experimenter makes his choice of measurement, the system is described by the wave function of the double-slit/experimenter/light system (although at first the experimenter has negligible effect). Both potential histories (blocking a slit/not blocking a slit) exist as a coherent superposition of the apparatus, the photon, and the experimenter. Then, if we close one slit at the very last minute, after the light has theoretically passed the slit system, we have now added constraints to the possible histories (and hence possible outcomes) of the system. The physical particle was not retroactively affected when the slit was covered, because the "physical particle" as such did not exist at that moment. Instead what has taken place is that by covering one slit we have universally narrowed down the field of possible outcomes of the experiment.

In the language of Consistent Histories, we narrowed down the collection of consistent families of histories to a smaller subset that is consistent with the *current state* of the overall system. A larger set X of histories existed before the experiment was performed, and we have now selected a specific subset of X that is consistent with the framework chosen by the experimenter. Other histories that are no longer consistent with the current double-slit/experimenter/light system are no longer available to the system.

The effects of choosing to block one of the slits has a universal or 'instantaneous' affect on the histories available to the photon, and the results of the measurement will be consistent with whatever history/timelines are available at that point. The measurement of the physical photon, however, will only be *detected* at light-like intervals, due to the asynchronicity effect. Any *physical representation* of an object will abide by the information travel limitations imposed by SR. This difference between the process of determining consistent histories (not restricted to SR requirements of finite information transfer time) and the process of taking a definite measurement (*is* restricted by SR information transfer at light speed) is the fundamental reason why the delayed choice experiment works.

## Interpretation

We should realize that even though light experiences no proper time intervals ($\Delta t' = 0$), this would not result in instantaneous information transfer, as one might intuitively conclude. This would instead result in a finite delay of travel in physical space-time equal to $T = L / c$ using the Lorentz transforms, as in equation (4) and equation (5). Light exists in a timeless state, but the results that relate two physically separated events will always be seen to propagate at a finite speed. This is to say that there is a minimum 'lag time' $T = L / c$ that an observer will measure between two events separated by a distance L.

$$t' = 0 = \gamma\left(T - \frac{Lv}{c^2}\right) = \left(T - \frac{Lc}{c^2}\right) \tag{4}$$

$$T = \frac{L}{c} \tag{5}$$

To be sure, we can use data collected about the events to infer after the fact that the events were simultaneous (this is called PE simultaneity or standard synchrony). We should note, however, that our approach implies a lack of a "common present moment." Instead, the "present moment" is defined relative to each observer, and any comparison of experience will involve a minimum lag time of T = L / c. Standard synchrony does not give us a valid notion of what *is happening*, it can only tell us retroactively what *did happen.*

Perhaps this point will be clearer if I put it differently. Consider an event A describing the emission of a photon at time t = 5:00pm, from any observer's perspective, and an event B describing the measurement of that same photon a distance L away, at time t = 5:20pm, from the same observer's perspective. Both events exist as specific coordinates in physical space-time, with a separation in the time coordinate given by T = L / c (a light-like separation). However, the light wave itself would not register a separation between the two events. The events are *observed as separate* in physical space-time because the asynchronicity principle dictates that the coordinate ($x_B$, $t_B$) in physical space-time will always be offset from the coordinate ($x_A$, $t_A$) by $t_B - t_A = L / c$, where $L = x_B - x_A$. Rather than saying, "light moves at the same speed c relative to all observers", we can say that any wave function that is present at ($x_A$, $t_A$), is also present at ($x_B$, $t_B$) as a superposition of possibilities, but for a material observer at ($x_B$, $t_B$) it takes a period of time L / c after $t_A$ for a single outcome to register in physical space. One could even say, paradoxically, that events A and B happen simultaneously for the inertial observer too, except with an offset of T = L / c.

The time zones drawn in Fig. 2 are a conceptual tool. In actuality they should be continuous, and they are true as drawn only when representing a photon moving from A to B, not in reverse.[1] For a photon moving from B to A, the time zones would be reversed. The difference between this proposal and the common sense notion that the "light is traveling" may seem simply like a matter of interpretation, but it is critical to my point. The explanation for why the light arrived at time 5:20 p.m. is not because "time has passed" or because "it was traveling." It arrives at this time because the asynchronicity principle causes this point in space to be advanced in time.

Finally, returning to the goal of this paper, we bridge the gap between QM and SR by saying that the state of the photon is not objective, nor continuous. It will only take a definite state when observed, and only relative to that observer. Although light has no sense of time or space itself, light will always be measured by an observer at a

[1] The 'time zones' due to asynchronicity always leap into the future, and never into the past.

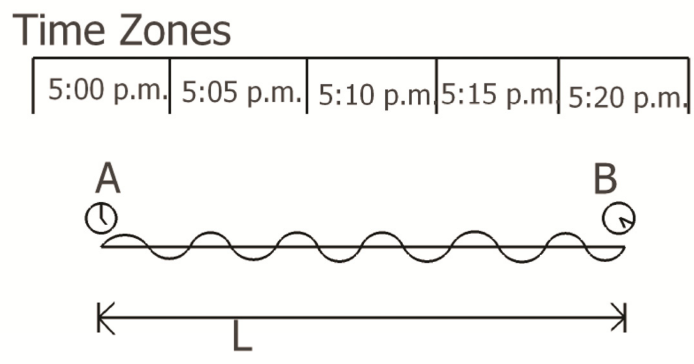


**FIGURE 2: "Time Zones for Light" – L / c = 20 minutes. Light's wave function connects points A and B simultaneously. However, the locations between points A and B are not all at the same time coordinate. A location L meters away will be advanced in time by L / c. The photon that exists as a result of this wave function will be observed to have traveled at a speed c, when measured.**

position and time exactly *as if* it had travelled at speed c continuously through the intervening medium. When we *do not* make a measurement or observation, we cannot say that the photon physically exists in a definite state. Rather, it exists as a mathematical entity representing all the possible histories.

## CONNECTION TO RETROACTIVE EVENT DETERMINATION

### Retroactive Event Determination

> *"Even if one allows for the possibility of retrocausation, that is, for the possibility of an effect preceding its cause in time, it is generally held that a present cause can not change or alter the past. It would merely make the past what it was." Steven Savitt* [6]

In [2] I pointed out a compelling aspect of Consistent Histories quantum theory that I termed Retroactive Event Determination (RED). In that paper, I applied RED to the states of not only microscopic quantum phenomena, but also to macroscopic scenarios. The idea can be summarized in the phrase "Events don't actually 'happen' when they happen," which is intended to convey the notion that the entire history leading up to an event E remains in superposition relative to a given observer until the observer makes a measurement of the event E. Not only is the state at the moment of observation determined through the observation of E, but the entire history of events leading up to that particular E must also be retroactively determined at that point. It was clarified in that paper that this does not involve retroactively *changing* the event history. Rather, any events which are in an unobserved/undetermined coherent superposition of states can fall into place retroactively, without any loss of consistency or conflict of causality, i.e. without changing any past 'facts'.

## Asynchronicity and RED

In the current paper, I'd like to make the connection between the principle of asynchronicity and RED. Simply put, for the case of light, the asynchronicity principle is the physical cause for RED. This can be seen by reviewing the conceptual steps we have taken to get here.

Step 1: The asynchronicity principle in SR leads to the claim that light registers no space-time separation between events.

Step 2: This claim means that the light must timelessly connect state A to state B.

Step 3: In order to adopt the view in step 2, and to preserve the notion (from QM) of an open future,[2] we must allow the state of the photon to be described as a coherent superposition of multiple possibilities, just before we do finally observe it. Otherwise, how would one specify which possibility was still open? Every possibility that is consistent with the constraints of the physical environment must still be available to the photon just before it is observed by a particular observer. [3]

As is shown later on, there is a strong case showing the "fully observer dependent reality" to be the only model of reality which fits the constraints of special relativity, general relativity, and quantum mechanics. This is also presented in postulate form as a given assumption of the arguments in [2].

Step 4: Finally, the previous steps require us to develop a theory of retroactive event determination. For if the photon has many various possible outcomes before we measure it, and our measurement is made out of free will (not pre-determined or pre-known), then the history of the photon cannot be determined up until the measurement is made. Clearly it is not just the event *right now*[4] that is being determined by the observation. Rather, it is the entire history of events which led to this outcome, given that the entire universe is behaving according to steps 1-3.

As an example, consider a photon released from thermonuclear fusion within the sun. The wave representation of the photon is a wave front which spreads out equally in all possible directions. The wave front contains information about potential interactions with various atoms in the environment, forming correlations, but not yet taking a definite state relative to any hypothetical potential observers on earth. Of course, the photon takes a definite state relative to the atoms it interacts with, but an observer on earth cannot form a definite statement about these unless they have some astronomical apparatus to take a measurement of those atoms. With respect to the observer on earth, the wave front is still undetermined and is in a coherent superposition. If we accept that the state of the light is undetermined at this point relative to an earth bound observer, we must also accept that the state of the dust particle it interacts with is undetermined for that same observer. For, if the state of the dust was objectively determined, surely this would also objectively fix the state of the light that had just interacted with it.

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[2] Here, we assume the reality of free will as well as the evidence presented by quantum indeterminism, i.e. vonNeuman's process 1 event evolution. These are addressed in more detail in the section "Philosophy: Ontology and Context Within the Literature."

[3] This is can be generalized to any 'observing' object, not just conscious observers. The light will only take a definite state relative to a speck of dust in space when it actually interacts with that speck of dust, and it will only be in a definite state relative to that speck of dust's description of it. However, specks of dust have very dull capacities to describe such interactions firsthand!

[4] Ignoring, for the moment, the ambiguity of the term 'right now' in physics.

Approximately 8 minutes[5] after the correlation event described above, an earth-orbiting telescope records an event of the photon striking the lens. Relative to the telescope's lens, the photon goes from being a wave spreading all around the surrounding space (approximately in a radial wave centered on the place of origin of the photon in the sun) to being a definite event occurring at the telescope lens. According to the telescope, the photon's state is detected, and it appears as if the photon has objectively traveled across the intervening space. Yet we must instead say that the entire history of this event falls into place at this moment, with respect to the telescope. Furthermore, for an observer on earth who has not yet witnessed the data from the telescope, both the telescope and the photon can only be described by correlated wave functions, existing in a coherent superposition of states. For if the state of the telescope was objectively determined, surely the state of the light must be too once it has interacted with the telescope. Therefore, whether the telescope has observed the photon, and even whether the photon has traveled toward that particular telescope or any other of the possible locations it could have ended up, are both still undetermined issues.

It should be emphasized that although there are countless possible states for a photon that is described by a radial wave originating at the sun, the number of states is also limited by the constraints of the geometry; namely that the photon can only appear on a spherical shell with a radius given by $L = cT$ (or on a more complicated surface if we are to consider all the potential interactions the photon has within the sun and within the space between the sun and earth). Thus there are an unimaginable number of possible states, especially when one considers all the potential interactions and their subsequent histories. In fact, one might assume that even if we go so far as to accept the idea that there is such a plethora of possible states available to the photon, still the *number of states* available to the photon must be a known quantity, even if it is not feasibly *calculable*. Yet it may even be possible to go further, and say that the number of states available to the photon, given the infinite complexity of any normal scenario, is truly *unknowable*. In that case, not only is the state undetermined, but the *number of possible states is also undetermined.* This last statement is pure conjecture, but it is to my mind a compelling area of future inquiry.

As a final note, it seems evident from this example that there cannot be a quantum/classical boundary. For, which events would count as 'real' and which events would count only as possibilities? Would the absorption of the photon by the telescope count as an objective collapse event? If so, then why not the individual interactions of the photons with dust in interstellar space? Decoherence theory may provide an answer to that question, but it is proposed in [2] that the fully relational universe invalidates the assumptions taken by the decoherence theorist. It seems clear that if we are to make the state of the photon undetermined until measured relative to a given observer (observer-dependent state) then we have no choice but to make the entire universe observer dependent, since the universe is interacting freely with that photon. In the work cited above, I present a mathematical argument in favor of this conclusion. The statement that 'the state of the photon is observer dependent' is not limited to the

[5] Actually, it is calculated by some estimates to take on the order of 40,000 years for a photon to actually escape the sun's surface after being created! That fact is irrelevant to our conclusion, but just adds to the mystery of the complexity of a truly relational universe.

situation where the light does not interact with the environment. As a result, any entity that interacts and correlates itself with the light must also itself enter into an observer dependent state.

# IMPLICATIONS

## Ubiquitous Existence of Synchronicity

> *"No empirical phenomena seem to demand a notion of backward causation for our understanding of them. And for a long time it was thought that such a notion involved either a contradiction in terms or a conceptual impossibility." Jan Faye* [7]

Synchronicity is a term coined by Carl Jung to describe series of events which seem to carry a meaningful connection for the observer, but are clearly not related by physical cause and effect. As a hypothetical example, imagine that you are starting a new business and feel totally overwhelmed by, say, the need to build a website for your business. You might have done significant research and come to feel that it is just more money than you can afford to pay someone to do it, yet it is clear to you that it is imperative to have a website for your business. You sit down on a cross country plane flight to see your grandmother, and in conversation with the person next to you, you realize that you both know someone in common. In further conversation you learn that the person you are talking to has designed a website for their own business using low cost Web 2.0 social media tools. In this case, you have learned about something that is highly relevant to you and greatly assists you in your goals, and yet is physically unrelated by cause and effect to your actions.

Alternately, if your spouse had seen your frustration with the website issue, had then called a "friend of a friend" and cajoled them into buying a ticket next to you on the plane and bringing up this conversation, then *that* would be an example of direct causality or physical cause and effect. But that is not the case here. Instead, an event F (learning about Web 2.0) happens that seems meaningfully related to some pre-existing event or situation E (difficulty with website), but is clearly not related by any kind of causal connection. What is particularly surprising about synchronicity is the distinct feeling one typically has that all along one has had free will over the choices of their actions, and yet this highly unlikely and fateful coincidence still occurred.

Now, it is not true that this paper directly predicts the existence of synchronicity. Yet the converse would be true; if synchronicity could be experimentally shown to hold true, it would provide evidence in support of the theories proposed here. I have proposed a model which could easily account for synchronicity, although I have not shown that synchronicity is a certain result of the theory. The example of synchronicity above could be physically accounted for using the mechanism of RED. Even though the person P (you) has the ability to freely choose any flight, at any time of day, and on any airline, the history of the person S (next to you) can remain undetermined up until you have made your choices. Then it is easily possible for the history of S to fall into place in alignment with the choices you have made, so that a certain, more meaningful, history is selected. Furthermore, the fully relational nature of the universe (i.e. only being able to describe the state of something from a specified point of view rather than globally) ensures that person S would have a continuous history that is consistent with yours, and would not herself feel like her history "fell into place" (from her perspective, her history developed continuously).

I am far from showing *why* such a "more meaningful history" might be selected by the laws of physics, but if such a mechanism could be described, the action of RED would be the proper descriptive tool. I will however, take a small step in the direction of predicting a process of "meaningful history selection." To understand my approach, consider that, up until now, we have described a model in which a photon exists primarily as a wave function in a realm of possibilities. Its existence could be modeled as a branching tree, and each branch represents one of its possible futures. Other objects in the environment exist also as branching trees, and the branches from their trees intersect with that of the photon at various points of interaction or correlation. The result is an (unimaginably large) network of correlations between the photon and the environment. Even with the existence of such a possibility network, it is unclear as to why any one branch would be more probable than any other branch. For instance, it may be sufficient to propose that the random probabilities associated with quantum processes determine the probability associated with each step of the branch.

However, let's make the model more complicated. Let us say that the photon in question is originating from the galactic halo (this example is based on a discovery made this month [8]). Let us imagine that such photons are rare, and the chance of seeing one is unimaginably low. As we have said, the probability wave for each photon spreads its magnitude over an (approximate) shell of galactic proportions, but in our case the experimenter's telescope happened to be pointing in that direction at a certain instant (as a result of their own free will). It is not until the observation is made of the photon that its particular history falls into place, and information about the galactic halo is now correlated to the experimenter's telescope. Let's call this time Y. However, the results are far from complete. There are many steps necessary before the experimenters are able to ascertain anything from the data they received, and there are many steps along the way in which they may be derailed in their efforts (the data may get corrupted, they simply may not look at the data in quite the right way, or that particular data point may simply be skipped over because it is too small to be noticed). So at time Y, the process of RED for the photon has brought the experimenters one step closer to a particular future result, yet that future result is far from certain.

In such a case, the RED of the photon (minor though it is) will have served to bring the experimenters *into a history in which the breakthrough discovery is more likely than it was before*. If we apply RED to macro systems, which are inevitably extremely complex, we begin to see that "meaningful history selection" could simply be a statement of the process by which an action E by person P results in a history in which other events correlated to E are more likely to occur for person P. Rather than endowing a psychological "meaning" to the events, we see that meaningful history selection is a result of our movement through the network of possible futures. Inevitably, our movement will bring us closer to events that are similar in nature to the types of actions we are taking (or the types of experiments we are running). So, hypothetically, the experimenters in the above research project will eventually have all the pieces of the puzzle line up in just the right way because their persistent actions towards a specific result brought about a branch of events for which almost every possible outcome of the scenario involved a successful result.

If such a behavior is indeed the case, it would suggest two things. For one, it is the long term, persistent actions that we take which determine the nature of the synchronicities we experience. Larger (less probable) synchronicities would involve greater persistence in action on the part of the individuals seeking a particular outcome. Secondly, it would imply that synchronicity is a very common, even ubiquitous occurrence. Clearly, it may not be evidenced very clearly, since small synchronicities (more likely coincidences) might seem rather commonplace and large synchronicities (less likely coincidences) can always be written off as a matter of chance. Yet based on the theory developed here, synchronicities of all sizes might be occurring constantly, and the lesser synchronicities would happen more frequently than the larger synchronicities.

It would be challenging to devise an experiment demonstrating the existence of synchronicity, yet I suggest that it can and should be done. By its very nature, synchronicity is unpredictable in exact outcome: no two synchronistic events are alike. After all, it is "meaning", as described above, which ties synchronicities together, rather than the familiar physical cause and effect. The macroscopic world is infinitely complex, and it is this complexity which makes synchronicity possible, albeit unpredictable. Yet, it should be possible to devise an experiment, whether in physics or maybe in an alternate field such as sociology, which demonstrates that events which are meaningfully related or similar in nature are more likely (than chance) to happen together.

## Spacetime from Causal Networks

As a final consideration I wish to discuss the idea that space-time itself is a result of causal networks, rather than the more popular notion that causality arises within space-time. This idea arises naturally from the asynchronicity principle discussed in this paper, since the location of a photon is not definite unless an observer makes a measurement. This implies that space and time do not have a well-defined meaning in the absence of an observer's measurement. This idea has been discussed elsewhere, such as D'Ariano and Tosini. "...the aim is to have the space-time endowed with SR emerging from the network of events, thinking of them not as "happening in space-time", but as making up space-time themselves." [9]

Although I agree with the starting point, they do not seem to make a careful definition of what an 'event' is, and are therefore unclear on their proposed structure of space-time. In one example, they propose a homogeneous structure of space-time "events" that define the space-time in which they occur, but this implies a perfectly composed structure of events, a quantization into homogeneous blocks of space-time. In this case, they must be implying that an "event" is something rather objective that occurs everywhere throughout space, and in such a way loses its connection to the familiar notion of an event as "something unique or definable happening." In fact, this particular example leads us to something that *might as well* be considered an ontological structure, since it is homogeneous and ubiquitous. If the space-time is structured in this way, then the structure seems imposed by some fundamental law of symmetry in order to create such a perfect lattice. Again, this seems to invalidate any attempt to establish "events" as the primary cause of space-time.

Such an approach of homogeneous structure is also evidently based on the assumption that the events that make up space-time have objective definiteness (for how else could we describe them with such precision and certainty?), and therefore that space-time has objective definiteness, which goes directly against the thesis I am presenting here.

It seems more natural to me to define an event as above: "some unique or definable interaction." Such events are *not* homogeneous (although they might appear so at various different scales), but are rather based on the chaotic nature of the interactions of the elements of the universe. Following this train of thought, and returning to the purpose of this paper, an "event" is considered to be any interaction. The only caveat is that those interactions will not actually be definite (i.e. physical) except in relation to an observer. Rather, at an objective level, the event is recorded as a correlation between two systems, and the states for those systems (relative to an external observer) branch into multiple possible options. The objective view only sees the correlations, and not the "actual states" (which are only relationally defined).

For example, clearly a photon (in outer space, for example) will have a continuous stream of potential interactions, such as correlations with dust particles, bouncing off molecular hydrogen, or striking the camera on the Hubble telescope. These interactions do not happen in any regular way, but simply according to the random layout of the environment. This is a natural and commonsense way to understand events.

With this definition as well as the caveat of relational states of things, I fully support the program attempted by D'Ariano and Tosini (and others) to describe the "events" of space-time as the source for defining space-time. Without the events, there is no space-time.

## PHILOSOPHY: ONTOLOGY AND CONTEXT WITHIN THE LITERATURE

The study of various forms of retrocausation is not new. The current theory proposed here, RED, does not strictly fall into the category of retrocausation, since it specifically disallows any *changes* to the past. Rather, the past can only be retroactively *determined* if it has not yet been measured by the observer. Still, we are touching on many themes that are well-developed in the literature and I would like to review how the proposed theory fits into these. I begin with a review of various paradoxes involving retrocausation. I then turn to an examination of the standard accepted philosophies of time, namely eternalism, presentism and possibilism.

### Retrocausation Paradoxes

In general, most paradoxes rest on assumptions, so my approach will be to understand these assumptions and show that they are not valid for RED. It is worth stating again that RED specifically does *not* claim that one should be able to change the past. From the Stanford Encyclopedia of Philosophy, *We have to make a distinction between changing the past so it becomes different from what it was and influencing the past so it becomes what it was. A coherent notion of backward causation only requires that the future is able to have an influence on what happens in the past.* [7]

The above sentiment applies here since RED only allows one to "influence the past to become what it was." Since it is a requirement of RED that the observer has no information about facts that he is to retroactively determine, it is clear that the past is simply becoming what it was, and no observer is able to prove otherwise. That last statement is a direct result of the relational nature of states, for any observers will agree on the states of things when they compare notes after the fact. But regardless, we have avoided the paradox stated above.

## *Bootstrap Paradoxes*

Consider the bootstrap paradoxes. "The bootstrap paradoxes arise in cases where you have a causal chain consisting of particular events in which *a* causes *b*, *b* causes *c*, and *c* causes *a*." [7] What is implied in the bootstrap paradox is an exchange of information at each interaction, e.g. from *a* to *b*, then *b* to *c*, then *c* to *a*. Such exchange of information is enough to fix a particular history in RED, and therefore not allow one to retroactively determine the events. In other words, the statement "*a* causes *b*" implies that event *b* has information about event *a*. Similarly, event *c* has information about event *b*. Therefore, event *c* has information about event *a*, so event *a* is fixed from the perspective of any observer that has information about event *c*. As a result, event *a* is not open to being influenced by event *c*. RED is always constrained by the observations that have been made. It would clearly not be allowable for any version of the bootstrap paradox to exist within the context of RED.

## *Consistency Paradoxes*

The consistency paradox is about maintaining the consistency between various observations by different observers at different times. Since RED is built on consistent histories quantum theory, the idea of consistency is embedded in its very structure. According to the Stanford Encyclopedia of Philosophy, "…the consistency paradox is no paradox as long as you do not insist on changing the past." [7] Issues of consistency arise when one attempts to change the past, because there are always dependencies associated with that change that would need to be altered to maintain consistency. Generally, this would be impossible if we lived in a block universe where everything was related to each other in a fixed way.

Within RED, however, the relational nature of states means that the relationships between events are not fixed. The only thing fixed is that a relationship exists. The exact nature of the information exchanged is not fixed, and therefore the dependencies that arise when an event is retroactively determined can always be amended to be consistent with all other information that the observer has. Greenberger and Svozil come to a similar conclusion: "The world may appear to keep splitting so far as the future is concerned. However, once a measurement is made, only those histories consistent with that measurement are possible." [10]

### *Andromeda Paradox*

In the so-called Andromeda paradox, two earth-bound observers are moving with respect to each other, and therefore have different hyperplanes of simultaneity, according to SR. The simultaneity/asynchronicity principle would dictate that observer A's reality is co-present with, say, March 4 on the calendar of a civilization in the Andromeda galaxy. Since observer B is moving with respect to A, he is co-present with a different moment in Andromeda's history, say March 9. Let's further say that a momentous decision to invade Earth (event E) is made on March 7 by the Andromedeans. In the words of Roger Penrose,

> *Two people pass each other on the street; and according to one of the two people, an Andromedean space fleet has already set off on its journey, while to the other, the decision as to whether or not the journey will actually take place has not yet been made. How can there still be some uncertainty as to the outcome of that decision? If to either person the decision has already been made, then surely there cannot be any uncertainty. The launching of the space fleet is an inevitability.* [11]

The Andromeda paradox is based on the assumption of objective definite states. It seems obvious to Penrose that it is impossible for a remote event to be determined for one observer and undetermined for another observer, yet this is exactly the prediction of Relational QM and RED. In fact, RED goes further and says that the event E is not determined for *either* observer until some information about it is gained, such as sighting the alien spacecraft in the sky hundreds or even thousands of years after event E. So the Andromeda paradox is not a paradox at all if one drops the assumption of objective definite states.

## Presentism, Possibilism, and Eternalism

> *"If backward causation is to be conceptually possible it forces us to be realists with respect to the future."* [7]

For reference in the next section, the following is a brief synopsis of the various schools of thought with regards to the philosophy of time, taken from [11].

In the A-theory school of thought, the present is special, and is differentiated from the past and future. This corresponds to the views of presentism and possibilism. There are two major ways to understand the A-theory of time: as ontologically privileged (each present moment exists, replacing the prior moment, is real in and of itself, and is distinguishable from the next moment), or as metaphysically privileged (the present flows across instants of time over an undifferentiated time scale).

The B-theory of time corresponds to the block universe. In the block universe, all of time exists, and the present is not unique or differentiated in any special way. The block universe already exists in its entirety, and so could be considered "static", as compared to the "dynamic" A-theory. Generally this view is held to be classical and deterministic. It is the view generally associated with eternalism.

## *Real and Unreal vs. Determined and Undetermined*

The main question being asked by the philosophers of time is regarding whether the past, present and future should each be considered 'real'. Yet the definition of 'real' in this context doesn't seem to be clearly defined by some philosophers. As Besnard says, "...it is clear that one cannot expect to answer the question about the reality of the past, the present and the future, if one does not give a sufficiently precise definition of reality beforehand. For instance, if one adopts a wholly mathematical ontology, that is, claiming that only mathematical objects are real, then eternalism simply follows." [13, p. 3]

In my view it is somewhat akin to the impossibility of defining "god", for there is no way to do so except through properties of nature which themselves have no explanation[6]. The closest I can come to understanding the philosopher's definition of real is something like "having a place in the ontology." But this is simply saying that what is real are whichever objects can be considered as real objects. Ultimately this seems to be of no help to my discussion here.

As we shall see, all the major philosophies of time rely heavily on trying to define whether the past, present and future is real or unreal (exist/not exist). I do not claim to have the technical background to be able to effectively argue against such an approach, but for the purposes of this discussion, I feel that the reliance on qualifying the past, present and future as real or unreal is essentially barking up the wrong tree.

Rather, the question of importance is regarding which things are definite and which things are indefinite. We will see that, according to the theory of RED presented here, the past consists of both definite and indefinite events, the present is mostly indefinite (except for the small sliver of reality being observed by a given observer at a given time), and the future is indefinite. What is relevant is that we can only consider an object to be *as definite as our current state of information* about that object.

Definite states should be considered to be part of a physical *and* mathematical ontology, whereas indefinite states are only part of a mathematical ontology. It is true that the indefinite states should not be considered physical, but whether or not we call them real seems not to be an important issue to me.

## *Eternalism*

Eternalism is the theory that has been most closely associated with SR. The reason for this is the principle of simultaneity/asynchronicity. "The special theory of relativity tells us that there is an infinity of planes of simultaneity passing through any given space-time point and that no physical test can distinguish one from amongst the lot. …we have no way to distinguish *the* present from amongst the multitude of presents." [6] For some, this was strong enough evidence to end the debate. The mathematician and science fiction writer Rudy Rucker said:

[6] Another commonly used and equally ambiguous word is 'exist'.

*As it turns out, it is actually impossible to find any objective and universally acceptable definition of "all of space, taken at this instant." This follows ... from Einstein's special theory of relativity. The idea of the block universe is, thus, more than an attractive metaphysical theory. It is a well-established scientific fact.* [14]

Another way to understand this conclusion is through the Andromeda paradox. Referring again to the Stanford Encyclopedia of Philosophy,

*It is easy to see that, by adjusting the speeds of Alice and Carol, any event to the future of O can be shown to be fixed or real or inevitable. But O itself was just an arbitrarily chosen point in the space-time. "It begins to seem that if anything is definite at all," we might echo Penrose, "then the entire space-time must indeed be definite! There can be no 'uncertain' future.* [6]

Or, as Besnard comments, "According to some it is more or less *reduction ad absurdum*: the Andromeda paradox … (is) simply incompatible with a three-dimensional view of reality, hence with presentism." [13, p. 5]

The eternalist standpoint is further developed within the discussion of black holes. As Besnard says, "The ontological status of the regions of space-time that a given observer is never informed about (e.g. in a black hole) is problematic. From a possibilist stance, the events in such regions are never in the present/past of the observer, thus they can never be considered as real…The eternalist creed is that there is an observer-independent reality taking all these partial observations into account." [13, pp. 15-16] In other words, there exist future observers observing future events, and similarly for the past. Every area of the universe is being objectively observed, including inside a black hole.

We shall see, however, that when one also takes into consideration the general theory of relativity (GR) and QM, eternalism does not survive intact. The aspect of eternalism that does survive and is incorporated into RED is the realness of the mathematical objects that represent the future. So in the end I agree with Besnard's portrayal: "Eternalist definition of reality: Reality is the totality of mathematical objects." [13, p. 22]

## *Presentism*

*"...presentism is notoriously difficult to combine with special relativity."Fabien Besnard* [13, p. 4]

Besnard's analysis of presentism is enlightening and complete, and so I will quote it extensively. The reader will understand that I am simply wishing to show the existing work that has been done, and how the conclusions drawn by others provide strong support in favor of the arguments I am making. Although eternalism seems at first to be the clear favorite of SR, Besnard shows that this is based upon the assumption of observer independent reality. If one drops this assumption, Besnard's conclusion is that presentism is compatible with SR.

Besnard says "...the Reitdjik-Putnam[7] argument (regarding the impact of Special Relativity on presentism) does not invalidate presentism outright, but forces it into incorporating the perhaps counter-intuitive idea that reality is observer-dependent." [13, p. 2] Accordingly, the only way to resolve the question of "Now" with the eternalism of special relativity is to consider reality as observer-dependent. This seems, historically, to be an unpalatable conclusion: "...many authors whose works argue for the incompatibility between presentism and relativity explicitly reject the idea of an observer-dependent reality." [13, p. 6]

To be more explicit,

> *...one cannot hold the three following theses for true at the same time.*
> *1. There is an objective, observer-independent reality.*
> *2. Philosophy of time has to be compatible with special relativity.*
> *3. Presentism is the correct theory of time.*
> *We think it is worth emphasizing that the arguments against presentism put forward by Putnam, Savitt, Saunders, and many others, all rely on a commitment to 1 and 2. On the other hand, it seems to us that most philosophers who wish to stick to presentism tend to eliminate 2…(but) keeping 2 while getting rid of 1 would be much more reasonable, opening the road for a theory of 'relative presentism'.* [13, p. 7]

Savitt arrives at the same conclusion, although his tone is much more skeptical, "... the presentist who takes STR seriously must take relativized presentism seriously." [4, p. S569]

The relativity of simultaneity forces the student of philosophy into one of two conclusions. Either all of time and space exist equally (the block universe), or the reality of time and space are relative to the observer. The second conclusion is the only stance available to the presentist. "...according to presentism, what is real for A when A is at O is what is simultaneous with O. But Einstein taught us that simultaneity is relative. Therefore reality is relative…Two observers might be at the same point in space-time and yet do not share the same reality. Thus, the presentist concept of reality must take the form of a relation between events, which depends on the observer." [13, p. 6]

So far, SR does not cripple presentism, but rather forces the presentist into exactly the same conclusions I am drawing in this paper. I do have differences, however, with the standard presentist view. According to Besnard, "...the presentist is forced to adopt a definition of reality which depends on the observer, and more precisely on the movement of the observer." [13, p. 6] I would alter this, and state instead that the presentist definition of reality depends on all the particular information that the observer has about the environment. The relative motion of the observer with the environment is only one small factor to consider. Again, what is physically real is

[7] Reitdjik-Putnam's important paper concluded that presentism is incompatible with special relativity.

considered as what one has actually witnessed, rather than what one could in principle have witnessed.

Returning again to the Andromeda paradox, presentism tends to assume that the backwards light cone of an observer defines their present, i.e. what they could have witnessed, *in principle*. Here I am stating that the present for an observer is defined by *what they have actually witnessed*. Therefore, when discussing aliens invading Earth from Andromeda galaxy, as mentioned earlier we must consider that the invasion only becomes real (for the given observer) when the aliens are actually witnessed by the humans.

I agree with Besnard that "...presentism and possibilism are naturally led to a purely empirical, positivistic, notion of reality." [13, p. 3] Although this is a fairly unpopular view, it seems to me that it is in direct alignment with the well-substantiated theory of QM, and hence brings us back to the aim of this paper. QM implies the indeterminacy of things for which we lack information, and this is exactly what is required to make presentism compatible with SR.

The same conclusion is achieved by Sklar in his use of the term "Inertial egalitarianism" [15, p. S570], although once again his use of the term is highly skeptical. "Each admissible reference frame is held to have its own present at E (as indeed it does). The presentist adds that reality is relativized to each such present…What is added by saying that E is real for Alice but not real for Bob?" [15, p. S570]

Evidently Sklar is one of the philosophers that Besnard refers to above who holds onto the notion of an objective definite reality, but his reasons seem mostly metaphysical. He freely admits that the notion of inertial egalitarianism is perfectly valid, but rejects it based upon face value. "Now there is nothing inconsistent or otherwise formally objectionable about such a relativized notion of 'reality for', but it does seem to take the metaphysical heart out of the old claim that the present had genuine reality and the past and future lacked it. For what counts as the present is only a matter of arbitrary choice, and so then is what is taken as real." [16, p. 297] I wonder if such philosophers would be slower to reject inertial egalitarianism if the proper physical theory existed to explain it. That has been a central aim of this paper.

## *PE Possibilism*

Possibilism is very similar to presentism, and has many of the same arguments pro and con. In possibilism, both the past and present events for a given observer are considered real for that observer, and I will draw the same conclusions as before of an observer dependent reality. There are two particular ways of viewing simultaneity (PE and OS) which give rise to two varieties of possibilism.

Poincare-Einstein (PE) simultaneity (or standard synchrony) relies on a general notion of objective reality. Otherwise put, we can infer what <u>did</u> happen and what <u>was</u> simultaneous, and this corresponds to some objective truth. Observed simultaneity (OS) states that *what is capable, in principle, of being observed* should be considered simultaneous (in other words, the backwards light cone of the observer). Visual representations of these are given in Fig. 3. In my view I would like to emphasize that

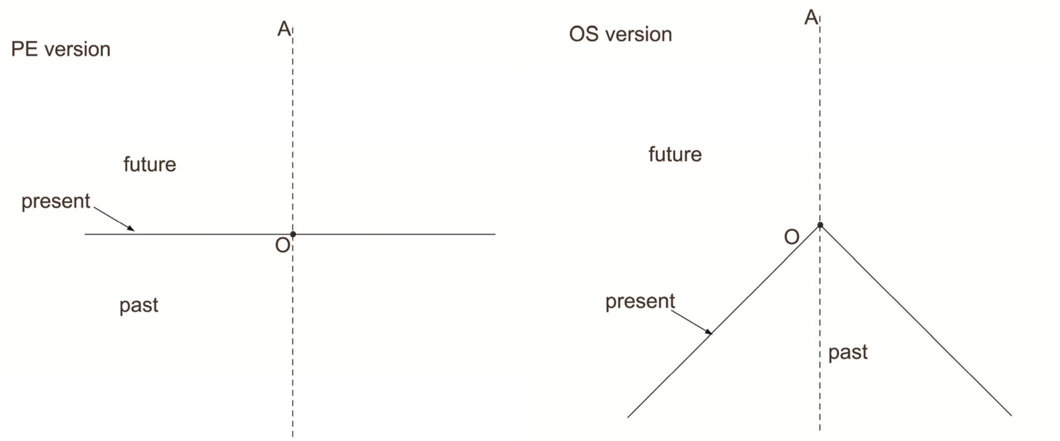


**FIGURE 3: Minkowski representations of the past, present and future according to PE simultaneity (left) and OS simultaneity (right). Reprinted with permission from Besnard.**

this is more than just "for all practical purposes." Rather it is a fundamental statement about what events can be described in a definite state.

In other words, let's say observer A receives information that event M happened. The difference between these two views is encapsulated in the question "What can be said before this information is gained?" According to PE an event M was definitely real and fixed immediately after it occurred. According to OS an event M becomes real when the backwards light cone of observer A intersects with M (i.e. when any light emitted at event M would theoretically hit observer A). According to the theory put forth here, the event M only becomes definite when information about M is gained by observer A, whether in the form of a light signal emitted directly from M in a light cone or any other more roundabout (and slower) method of information transfer. Note the distinction that the first two theories are describing what is "real" for a given observer, whereas the last theory is describing what is "definite" for that observer. According to the theory put forth here, all the possible unobserved outcomes with respect to event M are mathematically "real" but not "definite" for observer A, up until he gains information about M.

PE possibilism is problematic in the context of GR and QM. For example, if one considers an accelerated reference frame, then "there are events…that are in the past for A at some point and in the future at a later point!…The way out of the problem for the PE presentist/possibilist is to acknowledge that the present is not only a relative but also a *local* notion…he must set a spatial bound to his reality at O." [13, p. 12]

Besnard concludes that PE simultaneity requires a local definition of reality, rather than a global simultaneous reality. It seems to me that this is another way of saying that he can only define his reality around the information he has received. So the PE presentist/possibilist, when considering non-inertial reference frames in GR, is forced to adopt a view very much akin to the one proposed here.

In special relativity, because we can draw a plane through point O that defines simultaneity relative to an observer at O, we can therefore call simultaneity global or infinite in spatial extent. "But," says Besnard, "there is no way of defining unambiguously distant parallelism in general relativity, precisely because the curvature does not vanish." [13, p. 13] Because space-time is curved in GR, the spacelike hypersurface defining simultaneity (and defining the present) is not unique. In this context, PE presentism (based on a notion of an objective definite present) does not hold up. "There are an infinite number of space-like hypersurfaces intersecting A orthogonally at O, and each one of them can be used to define Gaussian (or synchronous) coordinates which are a possible generalization of Poincare-Einstein simultaneity. This renders PE presentism/possibilism untenable." [13, p. 14] Peter Evans mirrors this same point:

> *(For the A-theorist, objective temporal passage comes from)...a hyperplane of simultaneity within space-time which privileges a particular time instant and which embodies the passage of time. The problem ... is that no such hyperplane of simultaneity is privileged as such; due to the relativity of simultaneity, many hyperplanes of simultaneity can be specified depending on the relative motion of the observer and none of these can claim any special status as being a privileged time instant.* [12, p. 8]

On the other hand, as we shall see, OS possibilism does not run into the same problems with GR. "The OS possibilist version of reality for an observer at O (in the context of general relativity) would be the causal past of O." [13, p. 14] Even if one is in an accelerated frame or curved space-time, the causal past for a given observer is still well-defined. However, we will still be constrained to the notion that reality is observer dependent.

## *OS Possibilism*

In response to the comment earlier by Rucker, the distinguished philosopher and logician Arthur Prior thought that Rucker's conclusion (SR proves that eternalism is a fact) instead showed that special relativity is an incomplete view of reality:

> *One possible reaction to this situation, which to my mind is perfectly respectable though it isn't very fashionable, is to insist that all that physics has shown to be true or likely is that in some cases we can never know, we can never physically find out, whether something is actually happening or merely has happened or will happen.* [17]

This would tend to point to OS possibilism, the idea that the Now is defined by what one can (theoretically) have information about (i.e. all events within the backwards light cone).

In OS possibilism, there is no way to make a concrete statement about events which are outside of the observer's backward lightcone, even if they are in the past. "We see that in OS possibilism, reality is defined in terms of causality. An event M is real for an observer at O if something at M can influence this observer when it is at O." [13, p. 11] Again, I wish to revise this OS possibilist view by stating that the backward light cone represents the outer limit of what an observer could consider definite, but that what is actually definite is in fact far more constrained by what the observer has actual information about.

I have already pointed out that GR poses no problem for OS possibilism. “For OS …(the generalization of special relativity to non-inertial reference frames)...is obvious, since this version (of presentism/possibilism) does not depend at all on the movement of the observer.” [13, p. 12] Besnard concludes that the requirements of GR leave us only two remaining choices for a philosophy of time: eternalism and OS possibilism. “So there are only two options remaining...a ‘positivist’ trend for the possibilist, and an idealistic trend for the eternalist. The possibilist view narrows down to a strict empiricism, whereas the eternalist is more and more inclined to believe in an exact parallelism between reality and mathematical physics.” [13, p. 16] So if there is an objective definite reality, then eternalism is the only possible description of it (and I am out of a job!). If eternalism is not the case, then the only other option would be something similar to an OS possibilist/presentist view.

So how do eternalism and OS possibilism fare in the context of QM? Given the success of QM and its focus on the perspective of individual observers, it is a necessity that we incorporate the observer into any valid philosophical view of time. One might be concerned that we are creating a solipsistic framework by considering that reality is based on the information the observer has. In [2, p. 297] I argue that, because it is the mathematical ontology of all possible futures that is objectively real, it is perfectly fine to make the *individual* definite results of measurements observer dependent. The individual definite measurements in themselves do not make any objective statement about global reality, and therefore do not pretend to make objective reality observer dependent (solipsistic). Though some philosopher’s, such as Putnam, are concerned about the idea of solipsism in OS possibilism, Besnard points out once again that what they are really arguing against is an observer-dependent reality. “…Putnam immediately rejects (the OS definition of the present) because it would violate the principle that no observer is privileged in reality. However, we think that any observer is justified to see itself as privileged when it comes to defining its own reality. What Putnam rejects is that reality could be observer-dependent.” [13, p. 10]

As it turns out, quantum mechanics provides strong evidence against the objectivist viewpoint, making eternalism in the usual sense less tenable. According to the language put forth by von Neumann and standardized in physics, there are two very different kinds of events in quantum mechanics. Process 2 events represent the gradual (unitary) unfolding of systems in a deterministic fashion, according to the Schrodinger equation. Process 1 events, on the other hand, are stochastic, irreversible events, whose outcomes are based solely on probabilities. “One of the main arguments in favor of both presentism and possibilism is that of an open future…(i.e. free will)...If truly random events exist (in quantum mechanics), the idea that the future is open gains force, and it renders eternalism less credible.” [13, p. 16]

The multiple superimposed outcomes discussed in the sections above form a mathematical structure that seems to lend itself to the eternalist philosophy. It represents all the possible outcomes of every element in the environment (i.e. universe) constrained by the knowledge of the environment that a given observer already has. It seems, then, that the proposal in this paper preserves some aspects of the eternalist philosophy, since the future is represented by a mathematical structure that has ontological status. With regard to this same idea, Besnard says "The second way to understand 'pure probability' in quantum theory, is to say that they are not a crude model of a more detailed reality, but that, as far as we know, they *are* real. That is to say, the mathematical object which is called a probability exists in nature. It also means that its source set, usually called 'the universe', also exists. In it, all outcomes equally exist." [13, p. 19]

Besnard equates this view with eternalism and the Many Worlds hypothesis, neither of which is fully compatible with RED. It may be, though, that RED is an even better fit to the statement above. The concept that the mathematical possibilities of states are "real" (though not "physical") is directly compatible with the notion of observer-dependent states. If various observers will consider different things in the environment 'definite', then the 'actual' state of the environment is the superposition of all its possibilities, given the constraints of consistency between the observers. This is not exactly Many Worlds, and it is not exactly eternalism, though it does posit a mathematical field of possibilities which may be eternal and unchanging (see [2, p. 302] for a discussion on these matters). The view I take is somewhere between eternalism and possibilism/presentism, and fits well within the definition of 'pure probability' stated above.

To finalize the matter, Besnard states the Positivistic Postulate as follows: "Something which cannot be determined by an observer O at M, even in principle, is not real for O at M." [13, p. 17] This is nearly identical to the conditions chosen as prerequisite for RED [2, p. 285] (with the only change being that, as already stated, RED is based upon what information an observer *actually has*, not what they could have in principle). With this in hand, he concludes that "special relativity, quantum mechanics, and the weak positivistic postulate, rule out every theory of time except OS presentism and OS possibilism." [13, p. 18] As we have seen, OS presentism and OS possibilism directly imply observer dependent states.

Evans also comes to similar conclusions in what he calls the "proper time argument." To the presentist, "the (ontologically privileged) present is thus conceived as a privileged element of our reality which demarcates the past from the future in some objective respect." [12, p. 3] We know from SR that proper time is invariant under changes of reference frames, precisely because it is (by definition) what an observer measures for himself in his or her own reference frame. "The charge was made against the A-theorist (i.e. presentist) that there can be no objective temporal passage in Minkowski space-time because there is no scope for an objective hyperplane of simultaneity." [12, p. 13] So the A-theorist/presentist can only rely on proper time to describe an objective present.

The proper time argument is as follows.

> *...for future directed timelike curves there is an objective fact of the matter as to which events are past and which events are future. This temporal ordering of events is only local ... since observers at different space-time locations with varied relative motions will disagree on the ordering of spacelike separated, or nonlocal, events. One can then imagine any single space-time point on a future directed worldline as a candidate for an objective local 'now'. Minkowski space-*

*time would then contain many such local objective 'nows', each associated with a single worldline.* [12, p. 8]

Once again we are seeing that the scope of any objective notions of reality must be local, not global.

The proper time argument essentially says that the only objective, privileged now that can exist according to SR is given by the time measured in the reference frame of an observer relative to himself. This is clearly privileged, and is invariant under Lorentzian transformations, but it also clearly implies that, at best, the objective existence of a 'now' moment that we call the present is actually relative to a given observer. We are forced to return to the concept that the state of events in the present moment must be relationally defined with respect to a chosen observer.

In other words, time objectively passes for a given observer, and the only objective measure of time possible is that which is defined relative to a given observer. We find ourselves rejected from the B-theorists camp, since it usually refers to a block universe which contains a single observer-independent reality. This is clearly not our view. Yet we are also not welcome with the A-theorists because we have ruined any hope of calling the present moment ontologically privileged (although we still may be accepted as metaphysically privileged A-theorists). As Evans says, "…an ontologically privileged present *is* precluded … in general relativity. If one wanted to maintain that there were an objectively flowing privileged time instant, then one must understand this instant to be metaphysically privileged, whereby flow is interpreted as the evolution of the property 'presentness' across consecutive time instants that are ontologically undifferentiated." [12, p. 16]

Our way out, as stated before, is to allow a mathematical wave-function realism representing a block universe of infinite possibilities (a modification of the B-theory, static view of time). Yet events are only considered physically real (definite) relative to an observer. The present *is special* (an A-theorists view) because it is only in the present (relative to a given observer) that events become definite. So the present is physically real, but only relative to the observer. According to light, there is no such concept as present (as distinguished from future or past), and from such a view the hyper-block universe is the most reasonable description available (all possibilities exist and have always existed, but with probabilities that vary over time).

So it appears that most (if not all) of the valid arguments against the OS view of simultaneity are a matter of distaste with the notion of an observer-dependent reality. For example, Sklar point out that "...OS presentism (or possibilism) is a consistent doctrine, though not very popular." [13, p. 11] In the end, distaste is not a valid reason to discard the theory. Both views (PE and OS) then, when compared to special relativity, general relativity, and quantum mechanics, are refined to a single view: the definite physical present is defined by what one has observed, and yet the unobserved universe has mathematical ontological reality (though not in definite physical form).

## *Ontological Conclusion*

We have seen that the picture painted by RED is one which blends the ontologies of eternalism, presentism, and possibilism. Whereas the 'undetermined outcomes of quantum experiments' clearly indicates against the block universe, with RED a picture emerges of an extra-dimensional block universe; i.e. a block universe which accounts for all the (infinite) possible outcomes. This differs from the Many Worlds hypothesis since these many possibilities are not physically real. Yet the eternalist or mathematical realist view survives because we endow the mathematics of the wave function with ontological status.

Similarly, presentism survives, but only in part. Indeed, though with RED the present does have a unique status (where only one physical outcome exists), there are two marks against presentism. One, the present should be defined relative to the observer, and each observer will have its own present. Second, events should be defined to be in the present if the observer has knowledge (in practice, not in principle) about the event. Therefore, the present is a purely localized concept. There is no global present.

Finally, while meeting the most criteria for a valid view of time, possibilism also gets significantly changed when considering RED. Whereas in possibilism the past is generally considered fixed (if it is within the backwards light cone of the observer), according to RED, the vast majority of events that exist within the backwards light cone of the observer will not be fixed. This is simply because the observer will not have any information about them, and so they are free to be retroactively determined. Should we rightfully call such events the past? Or are they part of our local present? Ultimately, the concepts of past, present and future become less useful, in favor of the more accurate terms 'determined' and 'undetermined'.

RED manages to find a niche almost directly in the center of the three leading contenders for a theory of time. It keeps aspects of each approach, and provides a consistent model from their synthesis.

## CLOSING

I began by stating the conceptual gap that exists between SR and QM, whereby SR implicitly assumes the objective behavior of light, and QM forbids it. Using the well known equations and principles of SR, I have shown that this gap can be bridged with the simple requirement that the state of a photon is observer dependent. First, I noted the difficulty a photon would have in describing space and time intervals, and that the Lorentz transform requires that all space-time intervals as registered by light would be zero. Then, I renamed the principle of simultaneity to "asynchronicity" and showed that it is the cause of the observer dependent state of a photon. I have pointed out that in this model photons do not travel smoothly through space-time in an objective manner. Rather, they only can be said to exist in definite form when measured, at which time they appear *as if* they have been traveling smoothly over the intervening space at a light-like interval. In order for this to be the case, I argued that the destination state of the photon must be a superposition of possibilities, only one of which becomes actualized upon measurement. I have shown that the resulting theories of physics and metaphysics are consistent, with significant evidence in their favor. Finally, I made an analysis showing that the observer dependent state of the photon leads to the concept of retroactive determination of events (RED) as developed in my previous work. I argued that the requirement of observer dependent states of photons would inevitably lead to an observer dependent theory of macroscopic systems as well, as substantiated in previous work. As a conjecture I predicted that RED would be a perfect process to explain a physical phenomenon known as synchronicity, which under this theory would likely be ubiquitous in our everyday experience. Though presenting significant conceptual challenges such as irreproducibility, synchronicity should, in principle, be a testable phenomenon. If the ideas presented here hold up as valid, they will provide a simple and satisfying resolution of the century old conceptual gap between SR and QM.

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