Teleportative Observers versus Special Relativity Observers

The Logical Universal Chronology and Presentism

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Abstract
Various authors use the Rietdijk–Putnam argument while proposing that special relativity implies eternalism. For example, special relativity observers are limited by the relativity of simultaneity and cannot detect a preferred universal chronology. Any pair of special relativity observers that are causally disconnected to each other will detect ubiquitous relativistic reversals of chronology. The argument concludes that the reversals of chronology imply that all events in the past, present, and future exist "now." However, I introduce "teleportative observers" which cohere with wormhole theory based on various solutions of general relativity. Teleportative observers detect distant events and respective time dilation as if there were no macroscopic spatial interval and no other interaction between the observer and the events. Similarly, despite the relativity of simultaneity, the detection at a distance permits observers in causally disconnected regions of space to detect a universal chronology of events.

1. Introduction

The most perplexing prediction of Einstein's (1961) special relativity (SR) is the relativity of simultaneity. For example, two events are causally disconnected when the time interval between them is less than the spatial interval between them divided by the speed of light; while no two causally disconnected events are absolutely simultaneous to each other. This means that there is no coherent concept of an absolute universal chronology defined by the concepts of before, during, and after. However, scientific observation and human perception typically indicate a chronology of cause and effect. Likewise, there is no coherent concept of an absolute universal chronology, yet scientific evidence suggests the existence of some type of chronology. I call this the *SR chronology puzzle*.

The most prominent contemporary response to the SR chronology puzzle is the SR version of eternalism based on the Rietdijk–Putnam argument (Rietdijk 1966; Putnam 1967; Le Poidevin 1991; Price 1997; Savitt 2000; Penrose 2002, 299–305; Rea 2005; Wuthrich 2011). For example, eternalism states that the past, present, and future have always existed without tense; while concepts of eternalism go back to the presocratic philosopher Parmenides who argued against the reality of motion (Aristotle 350 BCE). Also, Propositions 1–4 define a generalized position of SR eternalism:

> **Proposition 1**. There is no possible preferred universal chronology.
> **Proposition 2**. Objects persist through the time dimension in the same way they extend through the three spatial dimensions.
> **Proposition 3**. All past, present, and future events have always tenselessly existed in what is called the *now*.
> **Proposition 4**. Tensed time is unreal and an illusion.

An alternative response to the SR chronology puzzle is the position of an observer in a hypothetical omnicluster of teleportative wormholes (Goetz 2016, 331–32). The hypothetical omnicluster does not teleport tangible objects but connects the observer to every event in the universe, including otherwise causally disconnected events. For example, Einstein and Rosen (1935) proposed a general relativity (GR) solution that predicts the possibility of wormholes that connect causally disconnected events in the spacetime universe.

This paper explores a thought experiment that focuses on the logic of the spacetime chronology while comparing the focal pathways of what I call *teleportative observers* and *SR observers*. For example, a teleportative observer has teleportative sight enabled by what I call *the hypothetical universal wormhole*. For instance, a teleportative observer does not teleport tangible objects but detects distant events and respective time dilation as if there were no macroscopic spatial interval and no other interaction between the observer and the events. Also, teleportative observers do not imply the existence of traversable wormholes. Furthermore, this logical analysis does not introduce new mathematical models.

In the rest of this paper, section 2 defines terms of logic and physics; section 3 describes the experiment in the context of causally disconnected observers, Big Bang cosmology, and multiverse cosmologies; section 4 discusses the experiment's implications for presentism versus eternalism.

2. Definitions for this Paper

2.1 Terms of Modal Logic

Definitions for terms of modal logic follow:

1. The adjective *hypothetical* refers to a coherent or incoherent imaginary thing.
2. The adjective *logical* refers to an internally coherent thing regardless if it coheres with the laws of nature.
3. The adjective *nomological* refers to a thing that coheres with the laws of nature.

2.2 Preliminary Terms of Physics

Definitions for preliminary terms of physics follow:

1. The *observable universe* is the physical universe that is potentially observable from Earth regardless of whether technology permits the observation.
2. An *unobservable entity* is a physical entity that technology cannot observe.
3. Newton's *absolute time* exists independently of any observer and elapses at a constant rate throughout the universe.
4. *Spacetime* refers to the four-dimensional unity of the three visible spatial dimensions and the one time dimension.
5. An *event* is a point and all its respective phenomena in the spacetime universe. The point has four relative coordinates that are three spatial coordinates and one time coordinate.
6. A *reference frame* consists of an abstract spacetime coordinate system and the set of physical reference points that align the coordinate system and standardized measurements.
7. An *inertial reference frame* is a reference frame without acceleration. *Acceleration* is a change of velocity.
8. A *closed timelike curve* (CTC) is a pathway for a particle that travels into its own past. A pathway for a particle or any physical object is also called a *world line*.

2.3 Special Relativity

SR is the theory of relative spacetime in the special case of no gravity. SR is based on flat geometry, which is Euclidean geometry. SR has two postulates. One, the laws of physics are identical for all inertial reference frames. Two, the speed of light is the same for all reference frames. This thought experiment looks at the SR implications of (1) the *relativity of simultaneity* and (2) *velocity time dilation*.

2.3.1 Relativity of simultaneity. The relativity of simultaneity implies that no causally disconnected events are absolutely simultaneous. For example, two events are causally disconnected when the time interval between them is less than the spatial distance between them divided by the speed of light. Also, the relativity of simultaneity implies the nonexistence of Newton's absolute time and Lorentz's (1904) preferred reference frame for a universal chronology that is held together by undetectable ether.

An interesting illustration of the relativity of simultaneity is a relativistic reversal of chronology of causally disconnected events. Consider the following example with *observer A*, *observer B*, *event A*, and *event B*. Each observer and event has its own reference frame in a spacetime region that is causally disconnected from the other three reference frames. Observer A detects event B before event A. Observer B detects event A before event B. This example exemplifies the relativity of simultaneity.

2.3.2 Velocity time dilation. SR implies velocity time dilation. For example, an observer with a higher relative velocity has a slower progress of time compared to an observer with a lower relative velocity.

2.4 General relativity

Einstein (1961) developed GR while using Riemann's mind-boggling curved geometry to add the effects of gravity to SR. For example, the Riemannian geometry of GR permits an infinite number of ways to define reference frames. Also, an observer at any point in the universe sees the same spatial scale factor in every direction. For instance, astrophysics confirms that the current spatial scale factor in every direction from every point in the universe is 46 billion light-years or 10^{23} kilometers. Furthermore, GR implies gravitational time dilations. For illustration, an observer in stronger gravity has a slower progress of time compared to an observer in weaker gravity.

Ironically, scientific consensus says that gravity is fundamental to the observable universe while there is no consensus for the cause of gravity. For example, Einstein (1961) stated that gravity is caused by the forceless interaction of mass and bendable spacetime. However, a current majority of gravitational physicists hypothesize the existence of unobservable gravitational force and the respective elementary particle called the *graviton* (Dyson 2012). For instance, Einstein's theory of forceless gravity has no quantum fields and likewise has no nomological possibility of interacting with quantum particles. However, gravitational force with zero mass coheres with quantum mechanics and Einstein's field equations for GR.

2.5 Wormhole Theory

Morris and Thorne (1988) and James et al. (2015) describe that a traversable wormhole has two ends, a throat at each end, no black hole, and zero distance between the throats. Also, the formation of temporary traversable wormhole throats would require exotic matter that causes a highly unlikely magnitude of the Casimir effect. Furthermore, given the exotic matter, James et al. (2015) describe that it is uncertain if the wormhole throats could be large enough and stay open long enough for the passage of a macroscopic object, such as a spaceship. However, the authors say that wormhole theory is nonetheless useful as a pedagogical tool for teaching elementary GR. Similarly, this paper uses wormhole theory and observers to describe what I call *teleportative observers* and *teleportative sight*. Next, I cite some wormhole research.

Einstein and Rosen (1935) proposed a GR solution that implies the possibility of wormholes which connect distant events in the spacetime universe. That is why a wormhole is sometimes called an *Einstein–Rosen bridge*. Later developments of wormhole theory include traversable wormholes (Bronnikov 1973; Ellis 1973; Morris and Thorne 1988; James et al. 2015), matterless wormholes (Gravanisa and Willison 2007), and quantum wormholes (Maldacena and Susskind 2013; Jensen and Karch 2013; Susskind 2016a, 2016b; Cao, Carroll, and Michalakis 2017, Susskind and Zhao 2018). Additional critiques indicate the nomological impossibility of wormholes with a CTC (Hawking 1992; Pati, Chakrabarty, and Agrawal 2011; James et al. 2015). However, Ringbauer et al. (2014) demonstrate that experimental simulations of a Deutsch (1991) CTC is logically possible.

I categorize traversable wormholes into two different types, that is, *teleportative traversable wormholes* and *time-traveling traversable wormholes*. A teleportative traversable wormhole could transfer a whole particle from one present location in spacetime to another present location. Alternatively, a time-traveling traversable wormhole could transfer a whole particle from a present location to another location in the past or future. However, limitations apply. A teleportative traversable wormhole is nomologically possible but highly unlikely. Also, a CTC could involve a time-traveling wormhole because a CTC would transfer a particle into its own past. However, as previously noted, a CTC is logically possible but nomologically impossible.

A recent development in wormhole theory is hypotheses of quantum wormholes which logically explain the unity of *action at a distance* in quantum entanglement (Maldacena and Susskind 2013; Jensen and Karch 2013; Susskind 2016a, 2016b; Cao et al. 2017; Susskind and Zhao 2018). Setting aside any extravagances of the cited hypotheses, what I call *the basic quantum wormhole hypothesis* says that an entangled pair of photons and their action at a distance are united by a quantum wormhole which is beyond direct detection. The photons that are otherwise distant to each other have zero spatial distance between them in the wormhole. This is the most logical explanation for the entangled action at a distance. Additional importance of the basic quantum wormhole hypothesis is that laboratories routinely generate quantum entanglement with action at a distance. For example, ground-to-satellite quantum entanglement with action at a distance has reached 1,200 kilometers (Yin et al. 2017).

The goal of the laboratory generated ground-to-satellite quantum entanglement is the development of *quantum teleportation* for future quantum communication and computing technology (Ren et al. 2017; Gisin 2017). The quantum teleportation has two major steps. First, the laboratory generates an entangled quantum system such as the previously noted ground-to-satellite quantum entanglement. Second, the quantum entanglement is used to *instantaneously* (1) destructure quantum information from the sending end of the entanglement and (2) restructure the same quantum information at the other end. I call this *restructural teleportation* as opposed to *whole teleportation*. Also, the basic quantum wormhole hypothesis implies that the laboratory generated quantum entanglement and restructural teleportation involve quantum wormholes.

The basic quantum wormhole hypothesis can also apply to new discoveries of quantum entanglement in astrophysics. Fascinating new research indicates that the universe is filled with entangled pairs of photons with action at a distance measured to a whopping 2,000 light-years, that is, 10^{16} kilometers (Handsteiner et al. 2017; Rauch et al. 2018). This action at a distance is mind-boggling when considering that there are 80 million stars within 2,000 light years of the Sun. The basic quantum wormhole hypothesis applied to the astrophysics data predicts that the universe is filled with quantum wormholes, including interstellar quantum wormholes, which are a capable medium for restructural teleportation. The quantum wormholes unite the photon pairs with zero distance between them in the wormhole regardless of the non-wormhole distance between them.

Also, as noted in the introduction, Goetz (2016, 331–32) proposes a hypothetical omnicluster of teleportative wormholes. The omnicluster of wormholes contains no throats and is not traversable, but it enables an observer to detect every event in the universe or multiverse as if there were zero spatial distance or no other interaction between the observer and each event. This enables a preferred universal chronology of events without an absolute spacetime scale. The proposal says that GR implies wormhole theory and does not depend on the existence of any actual traversable wormhole. However, the proposal needs modification because there is no consensus that GR implies wormhole theory.

Alternatively, I propose that teleportative observers and teleportative sight cohere with the subset of GR solutions that permit traversable wormholes given highly unlikely or nomologically impossible wormhole throats. Such GR solutions include James et al. (2015). Also, a teleportative observer does not teleport objects but uses teleportative sight to detect every event in the universe. The teleportative sight permits detection at a distance. For example, a teleportative observer detects distant events and respective time dilation as if there were no macroscopic spatial interval and no other interaction between the observer and the events.

Imagine hypothetical James et al. (2015) traversable wormholes. CTCs and all other time travel are impossible, but teleportation of small objects and visual perception through a wormhole are possible. Consider a model of an exotic wormhole throat that has a one meter radius and a microscopic length. Any pair of the throats have zero distance between them and looks like a temporary teleportation portal. Exotic matter generates the model traversable wormholes to any otherwise causally disconnected location. Observers on both sides of a model wormhole see each other as if there was no macroscopic distance between them.

2.6 A Relative Spacetime Coordinate System

Preliminary terms:

1. A *Planck time* is the theoretically smallest possible unit of measurable time; 1 Planck time equals 10^{-43} seconds, which is the time required for light in a vacuum to travel the distance of 1 Planck length.
2. A *Planck Length* is the theoretically smallest possible unit of measurable length; 1 Planck length equals 10^{-35} meters.

A relative spacetime coordinate system has four relative axes for each spacetime point, for example, (t, x, y, z). The time axis is (t) and the three spatial axes are (x, y, z).

In this thought experiment, the intervals for the axes (x, y, z) are Planck lengths and the intervals for the axis (t) are Planck times. For example, axis (x) is perpendicular to axes (y, z); the first interval is ($0 \leq x < 1$); the second interval is ($1 \leq x < 2$); the third interval is ($2 \leq x < 3$); and so on. Also, astrophysics indicates that the observable universe has a scale factor of roughly 46 billion light-years that equals (2.7×10^{62}) Planck lengths in any given direction from any given point in the universe. Therefore, axes (x, y, z) are currently three perpendicular lines with intervals that extend from (-2.7×10^{62}) to ($+2.7 \times 10^{62}$), and any observer is located on its own ($x = 0$, $y = 0$, $z = 0$). Furthermore, present cosmic time relative to observers on Earth is roughly 13.8 billion years or (8×10^{60}) Planck times, so a present observer on earth is located at ($t = 8 \times 10^{60}$). Moreover, other present regions of the observable universe could be relatively younger or older due to different histories of time dilation.

2.7 Chronology of the Big Bang

The Big Bang theory begins with the Planck epoch that was the first Planck time interval of the observable universe. The first Planck time interval possessed the initial singularity. For example, a singularity is a dimensionless point with infinite curvature and the initial singularity was a singularity with infinite density. The very early universe endured from the Planck epoch to the end of baryogenesis that is the first millionth of a second or the first 10^{37} Planck times. For instance, baryogenesis produced elementary fermions that are matter particles, such as quarks and electrons. In the context of Standard Model of particle physics, the first millionth of second exhibited the formation of 10^{90} particles that were mostly photons and 10^{80} fermions.

The fermions moved rapidly and probabilistically in the state of plasma. Their distribution throughout the universe was nearly uniform with small fluctuations of density. The distribution of the density fluctuations was also nearly uniform. The expansion of the universe and thermodynamics cooled the plasma. After 400 thousand years, the universe expanded and cooled enough for the formation of hydrogen and helium gas that mixed with the remaining plasma. The plasma and gas moved rapidly and probabilistically. Eventually, gravity formed the density fluctuations into molecular clouds that collapsed into stars.

2.8 Multiverse Cosmologies

Two categories of multiverse cosmologies are (1) inflationary multiverses and (2) the many-worlds interpretation (MWI) multiverses.

Inflationary multiverse cosmologies propose that a quantum fluctuation sometimes generates a universe pocket while the observable universe is one of the pockets (Guth 2007). Also, experimental physics in a pocket universe cannot detect another pocket universe, except through a hypothetical wormhole.

The MWI is an interpretation of quantum mechanics that includes multiverse branching while the observable universe is one branch in the multiverse (Everett 1957). Also, all possible quantum fluctuations are definitely actualized in the branching multiverse. Furthermore, experimental physics in a multiverse branch cannot detect another branch, except through a hypothetical wormhole.

2.9 Presentism and Eternalism

Presentism proposes that the present tense is objectively distinct from the past and future (Zimmerman 2011). My clarified presentism outlined in this subsection defines that only the present tense of elementary particles tangibly exist; while tensed modes support the existence of facts about past history and future possibilities. For example, past events included tangible objects that no longer exist; while factual history of those past objects exists in the present. Also, future possibilities do not tangibly exist while facts about future possibilities exist.

Scientific evidence that supports presentism includes the following. First, all elementary particles oscillate. Second, disorder in an isolated system probabilistically increases during the progress of time, according to the second law of thermodynamics. Third, experimental physics has never detected a past tangible object or a future tangible object.

In sum, *Proposition 5* states the central claim of my clarified presentism:

> **Proposition 5.** Elementary particles exist only in the present tense; while the present is objectively distinct from the past and future.

Alternative to presentism, SR eternalism is derived from the relativity of simultaneity described in section 2.3.1. For example, Rietdijk (1966, 341) says, "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 (our) moment that the latter is 'now' for us." Rietdijk refers to relativistic reversals of chronology predicted by SR and argues that any pair of causally disconnected observers would detect reversals of chronology. He then argues that the ubiquity of relativistic reversals of chronology implies that everything in the past, present, and future exist *now*.

As previously stated, Propositions 1–4 generalize SR eternalism.

3. The Thought Experiment

The thought experiment imagines two teleportative observers (sections 1 and 2.5), a relative spacetime coordinate system (section 2.6), and the chronology of the universe or multiverse (sections 2.7–8). Section 3.1 details the teleportative observers. Section 3.2 describes the chronology of the Big Bang. Section 3.3 describes the chronology of multiverse cosmologies. Section 3.4 summarizes what I call *the preferred focal pathway for a universal chronology*.

3.1 Teleportative Observers and the Relativity of Simultaneity

An SR observer detects events through an interval of flat space. GR adds gravity to SR and a standard GR observer detects events through an interval of curved space. Also, sections 1 and 2.5 describe teleportative observers which detect distant events with teleportative sight. This observation is detection at a distance. For example, a teleportative observer detects distant events and respective time dilation as if there were no macroscopic spatial interval and no other interaction between the observer and the events.

The rest of this section imagines two teleportative observers with *bifocal pathways*. One focal pathway is called *teleportative sight* and detects events through the above teleportative detection wormholes. The other focal pathway is called *spatial-interval sight* and detects events through spatial intervals that are subject to the relativity of simultaneity, which is the same pathway used by a standard SR or GR observer.

Imagine four objects called *observer A*, *observer B*, *event A*, and *event B*. Each of the four objects is located in a spacetime region that is causally disconnected from the other three regions. The observers A and B possess bifocal pathways.

According to the spatial-interval sight of observer A, event A occurs before event B. According to the spatial-interval sight of observer B, event B occurs before event A. This describes a relativistic reversal of chronology for the two events and likewise exhibits the relativity of simultaneity implied by SR and GR.

However, the teleportative sights of observer A and observer B are identical. They both detect event A and event B without a relative spatial interval.

For example, observer A and observer B detect the same chronology of event A and event B.

Imagine the above scenario with a four-part chronological order for each observer defined as (T_1, T_2, T_3, T_4):

1. The spatial-interval sight of observer A at T_1 parallels event A.
2. The teleportative sight of observer A at T_2 parallels event A.
3. The spatial-interval sight of observer A at T_3 parallels event B.
4. The teleportative sight of observer A at T_4 parallels event B.
5. The spatial-interval sight of observer B at T_1 parallels event B.
6. The teleportative sight of observer B at T_2 parallels event A.
7. The spatial-interval sight of observer B at T_3 parallels event A.
8. The teleportative sight of observer B at T_4 parallels event B.

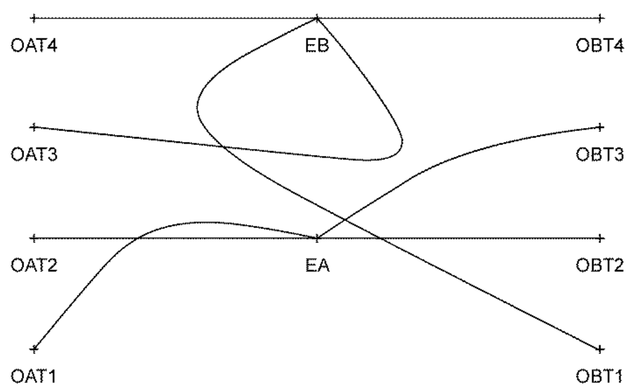

Figure 1. Schematic illustration of observer A (*OA*) at (T_1, T_2, T_3, T_4); observer B (*OB*) at (T_1, T_2, T_3, T_4); event A (*EA*); and event B (*EB*). Curved lines represent spatial-interval sight; straight lines represent teleportative sight.

The time parallels of the spatial-interval sight exhibit no transitivity as implied by the relativity of simultaneity. For example, consider the spatial-interval sights that detect EA:

1. OAT1 parallels EA.
2. OBT4 parallels EA.
3. OAT1 un-parallels OBT4.

The un-parallel times between OAT1 and OBT4 exhibit no transitivity. However, the time parallels for the teleportative sight exhibit transitivity. For example, consider the teleportative sights that detect EA:

1. OAT2 parallels EA.
2. OBT2 parallels EA.
3. OAT2 parallels OBT2.

The parallel time between EA, OAT2, and OBT2 exhibits transitivity.

3.2 The Chronology of the Big Bang

This subsection begins with two teleportative observers respectively called *observer A* and *observer B*. Also, all of the elementary particles in the universe are limited to the ones defined by the Standard Model of particle physics.

A spacetime coordinate system for Big Bang cosmology begins with the coordinates for the initial singularity, that is, ($t = 0$, $x = 0$, $y = 0$, $z = 0$) to ($t > 1$, $x = 0$, $y = 0$, $z = 0$). The experiment arbitrarily jumps to the end of the very early universe when there were 10^{90} elementary particles with an age of 10^{37} Planck times, and 10^{80} of the particles were fermions. The observers A and B were located at ($t = 10^{37}$) while they were causally disconnected to each other. Despite the relativity of simultaneity for causally disconnected events, observer A and observer B detected that events corresponding to the 10^{90} particles existed simultaneously because the observers detected with teleportative sight.

The different types of particles possessed different oscillation frequencies. For example, the photons possessed no mass and the fermions possessed mass. The differences of mass and other factors caused differences of velocity and gravity among the 10^{90} particles that caused relative time dilation. The different oscillation frequencies and the time dilation imply that the progress of time lacked synchronization throughout the observable universe.

The differences of the aging and progress of time increased because the distribution of the fermions throughout the universe was nearly uniform with small fluctuations of density while the small fluctuations eventually evolved into enormous differences of density, such as the density differences between intergalactic space and stellar black holes.

The observers A and B remained causally disconnected from each other. However, they detected the exact same chronology of every event in the observable universe because their teleportative sight is not subject to the relativity of simultaneity.

3.3 The Chronology of Multiverse Cosmologies

Observers A and B have no limits in multiverse cosmologies, such as an inflationary multiverse cosmology or an MWI cosmology. Observers A and B located respectfully in causally disconnected regions of a multiverse will detect the same chronology of every event in the multiverse because their teleportative sight is not subject to the relativity of simultaneity.

3.4 The Preferred Focal Pathway for a Universal Chronology

As previously mentioned in section 2.3, Einstein's SR implied the nonexistence of Newton's absolute time and Lorentz's preferred reference frame for a universal chronology that is held together by undetectable ether. GR added an infinite number of possible reference frames to spacetime. However, the impossibility of an absolute timescale does not imply the impossibility of a preferred universal chronology. For example, this thought experiment supports that teleportative sight is the preferred focal pathway for a universal chronology.

4. Discussion of Presentism, SR Eternalism, and Time Travel

SR eternalism is more popular than presentism among contemporary philosophers. However, the section 4 thought experiment implies that SR eternalism is a false position.

For a refresher, Propositions 1–4 define a generalized position of SR eternalism:

> **Proposition 1**. There is no possible preferred universal chronology.
> **Proposition 2**. Objects persist through the time dimension in the same way they extend through the three spatial dimensions.
> **Proposition 3**. All past, present, and future events have always tenselessly existed in what is called the *now*.
> **Proposition 4**. Tensed time is unreal and an illusion.

The experiment implies that Propositions 1 is false. As previously noted, Rietdijk (1966) based his argument on the assumption that a pair of causally disconnected observers definitely detect relativistic reversals of chronology. His assumption is false. Teleportative observers are a class of observers that avoid relativistic reversals of chronology. For example, teleportative sight is the preferred focal pathway for a universal chronology (section 3.4).

Only GR solutions that incohere with all wormhole theories and teleportative observers invalidate my thought experiment. This permits limited versions of SR eternalism. Likewise, the Rietdijk–Putnam argument coheres only with GR solutions that incohere with teleportative observers and likewise any model of wormholes.

Now, we consider Carroll (2010, 105–106). He leans toward presentism and the nomological impossibility of CTCs instead of eternalism and the nomological possibility of CTCs. However, he says that the nomological possibility of CTCs would definitively support eternalism and refute presentism because nomologically possible CTCs would not permit a series of present events. I agree with him that the nomological possibility of CTCs would not permit presentism.

As previously defined, a CTC is a world line for a particle that returns to its own past. Also, CTCs are a notable physics hypothesis of time travel into the past. Furthermore, I define that a CTC does not cause a new multiverse branch, such as an MWI branch. For example, if a particle travels to another multiverse branch through a world line that resembles a CTC, then the particle did not travel to its past, despite the other branch resembling its past. Therefore, the respective multiverse world line that resembles a CTC is not an actual CTC.

Back to CTCs, Ringbauer et al. (2014) developed a computer simulation of a Deutsch (1991) CTC. I suggest no fault in the logic of the CTC simulation; while I discuss problems with a critical assumption. For example, consider the logically certain Proposition 6:

> **Proposition 6.** CTCs and any other time travel to the past would require the tangible existence of past particles.

Proposition 6 suggests the importance of investigating the nature of the past when evaluating the possibility of CTCs and other time travel. Two prominent positions that imply the tangible existence of the past are SR eternalism and the growing block (Miller 2013). For example, SR eternalism implies that past, present, and future events tangibly exist; while the growing block position states that past and present events tangibly exist.

First, consider the possibility of a CTC in a growing block universe. The growing block's existence of the past might at first glance look promising for the possibility of a CTC. However, past events in a growing block never change. For example, a CTC would change the past unless the CTC has always existed. Therefore, a CTC is logically impossible in the case of a growing block because no CTCs or any tangible objects could have always existed in a growing block.

Second, consider the possibility of a CTC in an eternalist universe that coheres with Propositions 1–4. If an SR eternalist universe was possible, then a CTC logically could have always existed in an eternalist universe. However, Proposition 1 incoheres with time-traveling wormholes. Likewise, the Rietdijk–Putnam argument incoheres with CTCs.

Third, consider a CTC that has always exists in an eternalist universe defined by Propositions 2–4:

> **Proposition 2**. Objects persist through the time dimension in the same way they extend through the three spatial dimensions.
> **Proposition 3**. All past, present, and future events have always tenselessly existed in what is called the *now*.
> **Proposition 4**. Tensed time is unreal and an illusion.

One could imagine CTCs and other time travel in a hypothetical eternalist universe where objects persist through time in the same way they extend through space. For example, relativity implies that the time dimension and the three spatial dimensions and are four equivalent geometrical values on a four dimensional coordinate system. Also, traveling back and forth in time would be the same as traveling back and forth in space. Furthermore, any time travel would have always existed.

One could also imagine time travel in what I call a *pliable eternalist universe* that coheres with Propositions 2–4 while the past, present, and future have always existed with a pliable nature. In this case, traveling to the relative past and changing the past would immediately cause a ripple effect that changes its relative future. However, pliable eternalism implies the possibility of unresolvable paradoxes. Consider the following scenario. A mad scientist travels into the past and murders her grandfather before her father was born. The murder immediately eliminates her own existence because her father was never born. Then, she does not exist to travel into the past and murder her grandfather before her father was born. Then, her grandfather is not murdered; she exists; she travels into the past and murders her grandfather before her father is born. Then, she does not exist to travel into the past and murder her grandfather before her father was born....

Apart from possible unresolved paradoxes with pliable eternalism, consider major problems with Proposition 2. First, the fact that relativity implies that the three spatial dimensions and the time dimension have equivalent geometrical values on a coordinate grid does not imply Proposition 2. Second, no scientific observation has detected an object persisting through time in the same that an object extends through space. Third, scientific observation indicates that many tangible objects have taken a round trip through a spatial interval, but no scientific observation indicates that any tangible object has taken a round trip through a time interval. Fourth, scientific observation indicates the second law of thermodynamics; an isolated macroscopic system over time always exhibits a probabilistic increase of disorder, which is a violation of time-reversal symmetry. Likewise, the above four problems indicate that there is no scientific evidence for Proposition 2. Also, philosophical evidence for Proposition 2 in the context of relativity requires Proposition 1, while the only possibilities for Proposition 1 to possess a true truth value require a GR solution that incoheres with the possibility of teleportative observers and any type of wormhole. This brings us to the conclusion that Propositions 1–2 incohere with possible time travel through a wormhole. Moreover, Propositions 1–2 imply no support for the possibility of CTCs and the demise of presentism described in Proposition 5, that is, "Elementary particles exist only in the present tense; while the present is objectively distinct from past and the future."

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