

Solving Paradoxes of Time Travel Using the Many World Interpretation Theory

Author - Pratham Tekriwal

Abstract

The following paper aims to consider each universe as a separate quantum system and thus, aims to apply the basic principles of quantum mechanics to argue that no 2 universes share the same wavefunctions. We thus use the multiverse theory to solve the basic paradoxes related to time travel, in which reality transitions occur by shifting between pre-existing universes rather than modifying an existing one. Furthermore, the No-Broadcasting Theorem by Barnum et al. is applied to demonstrate that no two universes can share the same wavefunction, providing a rigorous basis for the uniqueness of each universe.^[7]

Introduction

Paradoxes related to time travel are often used as an argument against time travel, wherein scientists argue that time travel is not possible due to the existence of paradoxes like the grandfather paradox, which creates a logical contradiction during time travel. This paper aims to bridge the gap between these paradoxes and time travel to show the possibility of time travel, as well as multiple interesting questions that come with it, such as, “If time travel were possible, why haven’t we seen anyone from the future coming to warn us about the future?” This question will be addressed in the conclusion.

This paper explores the interplay between quantum mechanics, the conservation of information, and multiverse theory to build a self-consistent framework for understanding time travel and its implications for physics. I propose that changes in the past do not rewrite a single timeline but instead transition the observer to a universe where the change has always been a part of history, eliminating any paradoxes that arise with such a travel. Time travel, rather than modifying reality, may instead involve shifting between different universes with alternate versions of reality

1. Conservation Of Information, Energy and Mass

Before moving forward, it is imperative that we establish the fundamental laws that will be applied throughout this paper, which include the law of conservation of mass, proposed by Antoine Lavoisier, and the law of conservation of energy, established by James Joule, i.e., matter and energy cannot be created or destroyed, only changed in form.^[1,2] We also assume that information in a quantum system is also conserved.

This assumption is crucial because we will be treating our entire universe as a quantum system. If at all, the conservation of mass, energy, or information did not operate, then information could randomly appear or disappear, making it impossible to define a stable, predictable quantum state for the universe, and thus define this theory. By ensuring conservation, we ensure stability to effectively solve the time travel paradoxes.

If a traveller moves from Universe A to Universe B, does their mass leave Universe A, violating conservation laws? Since we treat each universe as a separate quantum system, conservation laws apply independently within each universe. The traveller's transition can be thought of similarly to quantum tunnelling, where a particle moves between states without violating conservation within either state.

2. Universe as a Quantum System and Application of the Many Worlds Interpretation Theory

At the smallest level, everything in the universe, from electrons to atoms, and even light, follows quantum mechanics. If the universe is made up of quantum objects, then it is reasonable to assume that the universe itself could follow quantum rules too.^[3,4] We thus use this argument to establish that we will treat every universe as a quantum system for the purpose of this paper, and thus, try to represent each universe as a wavefunction.

Using the Many Worlds Interpretation Theory, we show that there will be an infinite number of such alternate universes, each with an alternate version of reality, each described like^[3,4]

$$\Psi_{\text{universe}} = \Psi_1 \otimes \Psi_2 \otimes \Psi_3 \otimes \dots \Psi_n$$

$$(\Psi)''_{\text{universe}} = (\Psi)''_1 \otimes (\Psi)''_2 \otimes (\Psi)''_3 \otimes \dots (\Psi)''_n$$

.

.

•

Where each Ψ_{universe} function represent any form universe

Note that universes can also exist in the following form

Such universes are just a string of alternate combinations of wave functions of an electron that exist in the given universe.

Due to the presence of an infinite number of such universes, there is a universe representing each possible sequence of events where every reality can be described by a possible series of universes. While it is possible that the laws of physics differ in each of these universes, for the purpose of this paper, we will assume that the laws of physics continue to stay uniform throughout the universes, this would thus mean that the classical laws such as the law of conservation of mass and energy would apply to all these universes.

3. Implication of the Many World Interpretation on time travel

Ultimately, when we do change the past or the future, all we are doing is changing the positioning of some electrons, and thus changing the wave function through which the universe is represented. However, since a universe already exists with the same wave function due to the Many World Interpretations, and the presence of infinite universes, each with a different reality, there exists a universe for all possible series of events and realities. Hence when we do make a change to a given universe, there is already another universe with the same reality already existing that we just created.

Thus, the paper proposes that instead of the reality changing in the universe that we time travelled in, we are transferred to the universe where our change had always been a reality. This not only resolves paradoxes related to time travel such as the grandfather paradox, but also explains why we have not met a guest from the future yet, simply because even if a time machine is indeed going to have been invented in the future and be used to time travel into the past, there will be no way for us to make it out, because the minute a change, rather any change is made to our existing realities, the traveler would be transferred to a universe where that had already been a reality, and be reduced to mere spectator. Does the traveller's presence in the new universe constitute a measurement, collapsing its wavefunction?

I argue that it won't, simply because when we interact with such a universe in such a way, quantum decoherence will occur. Decoherence occurs when a quantum system interacts with its environment, causing it to lose its quantum properties and behave classically.^[5] When the traveller enters the new universe and begins interacting with it, decoherence would cause their perception of that universe to collapse into a single classical reality, explaining why they experience a stable, definite world rather than a superposition, but how can the universe lose its quantum nature, and whether a universe can even exist without quantum nature, you ask? The answer is simple, this reality will remain relative to the observer only. The universe remains in a superposition relative to an external observer, but for the traveller, the wave function collapses their perception to a definite classical state. Only the observer shall experience the new universe in a classical way; the universe will continue to be as it was, but just with a guest. The many-worlds reality continues to exist at a higher multiversal level, but the traveller is only

aware of one branch at a time. In other words, their presence in the new universe doesn't change its quantum nature, but it changes their perception of it.

So, how does the person reach that alternate reality? I propose that the transition takes place with the help of wormholes. Though the existence of wormholes cannot be proved, they continue to be the only mode of transport that we currently know of that would be able to transfer the traveller from one point in a given universe to another universe altogether.^[6] Thus, there is no change in the present timeline when we modify reality, but we will be transferred to an alternate universe with the same reality at the same point of time.

4. Implication of No Broadcasting Theorem

However, this raises an important question, "Is it possible for 2 of these universes to be represented using the same combination of wave function of electrons?"

The straight answer is no. This occurs due to "noncommuting mixed states cannot be broadcast" by h. Barnum et al. (1996), which states that "Given a general mixed state for a quantum system, there are no physical means for broadcasting that state onto two separate quantum systems, even when the state need only be reproduced marginally on the separate system."^[7] Note, that we consider universes as non commuting mixed states simply because the order in which we consider these universes matters a lot, because since this theory assumes the existence of alternate realities in a single frame of time, then the difference if we bring that change in Universe A or Universe B first matters a lot, because interacting with one universe may alter the way that the other one behaves. Consider that there are 2 universes (A and B) represented by 2 different wave functions. Suppose I change the reality in A first in such a way that I reach universe B, but then I again change the reality in such a way that I transfer back to Universe A. But had I done the same change done in A initially to Universe B, perhaps I would have reached another Universe C, meaning that 2 universes such as these represented by 2 different sets of wave functions are not commuting in nature.

This non-commutativity satisfies the condition required by Barnum et al., under which broadcasting is impossible, thereby confirming that no two universes can share the same wavefunction.^[7]

Conclusion

Time Travel continues to be the dream of science fiction enthusiasts throughout the world. It is incredibly unfair to rule out the possibility of time travel simply because of logical and contradictory paradoxes. With access to quantum mechanics, the paper has aimed to bridge the gap between the paradoxes of time travel and its solutions using the Many Worlds Interpretation of quantum mechanics, where a time traveller, instead of changing the past in a single timeline, would move into a universe where their actions were always part of history. Quantum decoherence ensures that they would experience a stable reality.^[5] The physical mechanism of transition between universes remains an open question. Wormholes, as theorised by Einstein and Rosen and later expanded upon by Thorne et al.^[6] represent one theoretical candidate, as they allow for connections between distant points in spacetime. However, this paper does not claim wormholes as a definitive mechanism — rather, it proposes that some such mechanism must exist if the framework described here is physically realisable. Finally, the absence of future visitors is naturally explained. Any traveller making a change upon arrival would immediately transition to a parallel universe, making them invisible to the original timeline entirely. While this idea is still theoretical, it provides a fascinating way to think about time travel and the nature of reality.

Citations

1. Lavoisier, A. *Traité élémentaire de chimie*. Cuchet. 1789.
2. Joule, J. P. On the calorific effects of magneto-electricity, and on the mechanical value of heat. *Philosophical Magazine*. Vol. 23, pg. 263, 1843.
3. DeWitt, B. S. *The many-worlds interpretation of quantum mechanics*. Princeton University Press. 1973, https://cqi.inf.usi.ch/qic/everett_phd.pdf.
4. Tegmark, M. The interpretation of quantum mechanics: Many worlds or many words? *arXiv*. 1997, <https://arxiv.org/abs/quant-ph/9709032>.
5. Zurek, W. H. Decoherence, einselection, and the quantum origins of the classical. *arXiv*. 2001, <https://arxiv.org/abs/quant-ph/0105127>.
6. Morris, M. S., Thorne, K. S. Wormholes in spacetime and their use for interstellar travel. *American Journal of Physics*. Vol. 56, pg. 395, 1988, <https://doi.org/10.1119/1.15620>.
7. Barnum, H., Caves, C. M., Fuchs, C. A., Jozsa, R., Schumacher, B. Noncommuting mixed states cannot be broadcast. *Physical Review Letters*. Vol. 76, pg. 2818, 1996, <https://arxiv.org/abs/quant-ph/9511010>.

