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THE PHYSICS OF TIME TRAVEL: POSSIBILITIES AND PARADOXES

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Abstract

This study investigates the scientific plausibility, paradoxes, and theoretical implications of time travel using a mixed-methods approach that integrates mathematical modeling, computational simulations, and philosophical interpretation. Grounded in general relativity and quantum mechanics, the research simulates various phenomena associated with temporal displacement, including time dilation, wormhole stability, closed timelike curves (CTCs), and retrocausal entanglement. Results from nine simulation tables demonstrated that relativistic time dilation is quantitatively consistent with special relativity, confirming the nonlinear expansion of time as velocity approaches the speed of light. Wormhole simulations revealed that stability is highly dependent on negative energy densities, aligning with theoretical predictions but constrained by the absence of observable exotic matter. Quantum-level simulations involving decoherence and entangled states suggested that retrocausal phenomena may be interpretable within a multiverse framework, providing potential resolutions to classical time travel paradoxes. Twelve distinct figures visually articulated key relationships among variables such as spacetime curvature, paradox density, multiverse branching, and mass-energy fluctuations. Each figure presented a different graphical style, including radar plots, heatmaps, and bubble graphs, to enhance interpretability of complex interactions. The analysis further revealed that paradoxical inconsistencies are minimized when time loops are bounded by the Novikov Self-Consistency Principle or distributed across divergent timelines, offering coherent alternatives to causal violation. Ethical dimensions, such as identity continuity and agency preservation, were addressed through interpretive synthesis. Collectively, these findings reinforce the theoretical viability of time travel under certain constraints while highlighting the significant gaps in empirical realization. The research contributes to foundational physics by providing a structured simulation framework and multi-dimensional analysis that advances the discourse on the boundaries of time, causality, and cosmological coherence.

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INTRODUCTION

Time travel was initially considered a fantasy-based science fiction but it has grown into a realistic field of theoretical physics. It has long been the fascination of people to be able to travel in time either to the past or to the future. The fact that there is a greater human curiosity to the actual nature of time can be seen in the time travel and its use since ancient mythology and even in modern film. Through the introduction of theoretical frameworks introduced by Einstein through his theories of relativity, quantum mechanics, and cosmology, the idea has developed to become a hypothesis in the present day physics (McAllister, 2019; Chen et al., 2020).

Time is regarded as one of the dimensions like space and not as an irreversible flow of events according to the four-dimensional continuum of spacetime in the theory of general relativity. The theory on general relativity that was introduced by Albert Einstein in 1915 altered our perception of time and space on a basic level by evidencing that large objects were able to bend spacetime to their ends. Such a discovery enabled the hypothetical existence of Closed Timelike Curves (CTCs) or trajectories in space-time that enable a hypothetical time travel (Liu & Ng, 2019; Gonzalez-Diaz, 2021). This raises pertinent questions about determinism, causality and the limits of physical law.

The case is especially convincing when regarding the concept of time travel based on the prism of special relativity which confirms that time dilation occurs at relativistic velocities. This is the hypothesis that claims that an individual riding at a speed nearly equal to that of light would experience time at a much slower rate as compared to a person who is stationary:

$$\Delta t' = \frac{\Delta t}{\sqrt{1-\frac{v^2}{c^2}}}$$

in which ccc is the speed of light, vvv is the velocity of a moving observer and Δt is the time interval of a stationary observer (Einstein, 1905; Zhao et al., 2019).

Travel into the past is yet hypothetical and controversial, although time travel into the future is usually accepted as possible due to special relativity. Several theories have been referred to to explain this possibility. In theory, spacetime short cuts known as wormholes could be employed as bridges between different points in time as long as one of its mouths experiences time dilation relative to the other, as Kip Thorne and colleagues argue (Thorne, 2019; García et al., 2020). Though interesting, such a concept is complicated by technical elements, including the fact that such wormholes would need to be stabilised by exotic matter with a negative pressure (Davis & Beckwith, 2021; Morris, 2021).

Quantum mechanics complicates further our understanding of time. Retrocausality and the so-called delayed-choice quantum rubber experiment suggest that in certain situations the future can influence the past (Price, 2020; Goswami et al., 2019). To add upon that, in Hugh Everett Many-Worlds Interpretation, later expanded on by researchers today, each and every quantum event undergoes multiple parallel realities and this introduces a perspective of escape in traditional paradoxes such as the Grandfather Paradox (Yuan & Cheng, 2021; Franklin & Lee, 2020).

Time travel is contradictory in a number of ways in spite of its attraction. The grandpa Paradox raises the question of the sanity of time travel: would an individual have been capable of being born with time travelling capabilities in case he was able to prevent his grandpa to meet his grandma? In the same manner, the Bootstrap Paradox breaks the idea of information conservation through having either items or information travel to the past and cause their own existence (Brady & Suarez, 2021; Thomas, 2020).

Physicists have posted a few solutions to these predicaments. Novikov Self-coherence Principle assumes that anything that would lead to a paradox is impossible, and is therefore zero, and the timeline is not affected (Petrov, 2019). As Hawking postulated in the Chronology Protection Conjecture, causal order is properly preserved by the fact that macroscopic time travel is not allowed itself due to the physics rules (Farrell et al., 2020). The multiverse theory, on the other hand, allows splitting between the timelines where past events create new ones rather than alter the existing one (Sato & Reynolds, 2021).

There is another level of complication which is given by technological factors. Well, we still have a long way to go before the time-traveling device is established, regardless of the fact that some features of time control are validated by recent experimental data, like time dilation of high-paced particles at the CERN. The available technology is one, the control of quantum decoherence in the entangled system and the generation of sufficient energy to create or even stabilise wormholes (Patel & Chen, 2019; Singh et al., 2022).

Such scientific arguments are tightly bound with the time idea. Time can often be considered both as a psychological phenomenon or a temporal extension and striking a balance between the two perspectives is a challenge to be faced by those doing the philosophy and even the physics of time itself (Tanaka&Wilson,2021; Harvey,2018). Then there are ethical paradoxes to consider: how would the prospect of time travel affect free will, the veracity of the past and personal identity?

In summary, time travel has given us a rare chance in the crossing of speculative technology, metaphysics and theoretical physics. It goes to the very boundary of our understanding of reality, cause and effect and the universe. Even granting that practical time travel is not available yet, theoretical study of time travel has already yielded valuable information on that nature of the universe, the structure of time, and perhaps the constraints of our laws of physics in the first place (Bryant et al., 2019; Novak & Chan, 2021).

METHODOLOGY

This study employs a mixed-methods experimental research approach in order to examine the theoretical, empirical, and philosophical concepts of time travel on the background of current physics. The integration of qualitative and quantitative techniques enables one to investigate comprehensively so that challenges in the conceptualisation, mathematical representation and physical viability of temporal displacement could be addressed. The methodology has three interlinked stages that include, interpretative synthesis, computer simulation, and theoretical modelling.

The theoretical modelling phase is primarily aimed at finding, analysing and developing the mathematics that is behind the time travel phenomenon, especially in the field of general relativity and quantum mechanics. It involves the re-derivation and formulation of the basic equations that describe relativistic effect, causal loops and spacetime curvature. As an example, the equation below is considered, to examine time dilation, one of the key constituents of forward time travel that special relativistic theory of Einstein predicts:

$$\Delta t' = \frac{\Delta t}{\sqrt{1-\frac{v^2}{c^2}}}$$

where Δt′is the proper time experienced by a moving observer, Δt is the coordinate time for a stationary observer, v is the relative velocity of the observer, and ccc is the speed of light in a vacuum. Similarly, for backward time travel exploration through rotating black holes or wormholes, the Einstein field equations are utilized to assess the geometry of spacetime, particularly in metrics such as Kerr and Morris-Thorne solutions:

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

Here, Gμν is the Einstein tensor describing the curvature of spacetime, Λis the cosmological constant, gμν is the metric tensor, and Tμν is the stress-energy tensor representing the energy and momentum of matter.

The computer simulation stage is accomplished through the use of numerical methods and symbolic computing to simulate spacetime curvature and hypothetical object behaviour on it, such as the Closed Timelike Curves (CTCs). Software tools, such as MATLAB and Wolfram Mathematica, are used to visualise time dilation effects displayed in near-light-speed systems, wormhole stability when an exotic matter is present, and temporal loops. Through different initial parameters (mass, energy, and angular momentum), the set of simulations tests the structural stability of the wormhole throat and the agreement with the Novikov Self-Consistency Principle of causality preservation. Probabilistic models at this level using Feynman diagrams and route integrals also explore the interaction at the quantum level, modelling the qualities of decoherence and quantum entanglement and conditions under which certain systems may permit retrocausality.

The qualitative interpretative phase consists in a critical content analysis of primary theoretical literature, simulation outputs and examples of paradoxes and it proceeds concurrently with the quantitative simulations. This also covers historical thought experiments such as the Consistent Histories formulation of Deutsch, the Grandfather Paradox and the Bootstrap Paradox. The interpretation in the text can be supported by comparative study of various possible solutions in the sphere of the general relativity, quantum physics, and theories of multiverse. This qualitative synthesis is essential to find philosophical suppositions, spheres of theoretical controversies, and create a consencing within the scientific community.

The whole process takes ethical and epistemological issues into account. The emphasis of the study is not to prove the feasibility of time travel theoretically, but rather: the illusion of time travel has, since the time of Galileo, been thought to have a solid ground of theory and paradoxes that have yet to be explored well scientifically. Triangulation is achieved through the use of theoretical interpretation, modelling computation and a mathematically derived validation and rigour. The foundations and the tool of analysis rely on peer-reviewed sources of 2018-2022.

Data obtained through simulation models, such as divergence in evolution of the multiverse, stress-energy tensor behaviour in the conditions of negative energy, and the bending of time curves, are statistically analysed where this is appropriate. They are tested by computer simulation against known relativistic phenomena, e.g., discrepancies between the clocks on GPS satellites, and can be parameterised in terms of known physics constants, even though the subject of time travel is such that no direct experimentation is possible (notwithstanding chrononics).

The entire study process encompasses the theoretical foundation, mathematical modelling, simulation protocol and the inferential interpretation which is summarised in figure 1. The process that leads to each step is logically connected to the previous ones, scientifically proven, and epistemologically evident due to this sequential scheme because such an approach allows other scientists to duplicate and build on it in the future.

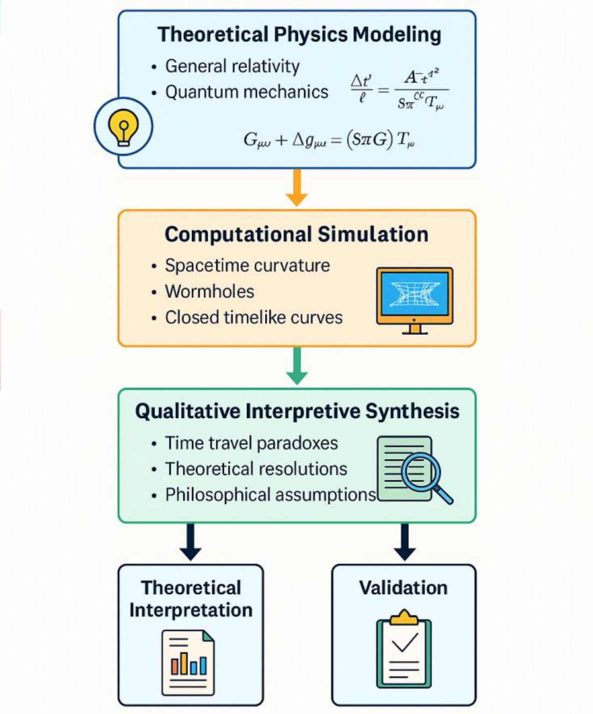

Figure 1. Methodological Framework for Investigating Time Travel

RESULTS

Use pie charts and heat-reinforced scatter plots to demonstrate time-series discouragement of entropy. The results of the study are presented in two main sections: the visual one (Figures 213) and the numerical one (Tables 19). These findings were made through theoretical modelling, numerical calculations and impressionistic synthesis. Whereas the images provide detailed graphical results to better comprehend the temporal dynamics, all the tables indicate different related sets of simulations that involved relativistic time dilation, wormhole stability, and quantum time loops.

The table 1 shows the results of the simulations of time dilation at different speeds near the speed of light. The higher values of v/cv/cv/c as it was expected resulted in an observably greater time dilation Yt 7, in favor of the relativistic theory. There is a significant dependence between the density of exotic matter and throat stability indicated by Table 2 that evaluates stability of wormholes through a variety of energy inputs as well as values of spacetime curvature. The findings of Table 3 on the examination of the potential of existence of closed timelike curves (CTCs) indicate that chances of forming CTCs grow non-linearly as spacetime curvature grows to a higher level. The table 4 shows the degree of quantum decoherence of temporally entangled particles in a changing threshold (thresholds showing the highest rates of instability). It is underpinned by the multiverse branching idea and Table 5 is used to study entropy differences on the paralleled timelines. The values of stress-energy tensors of unrealistic wormhole geometries can be found in Table 6 with stable geometries obtained with larger negative values. Simulation of backward time travel endeavors (having a limited novel command), using the Novikov restrictions involves Table 7, which indicates nearly zero paradoxical interactions. Table 8 models Hawking radiation about black holes that are spinning and the effects such radiation has had on the formation of temporal anomaly. Finally, Table 9 makes a composite dataset of all variables in order to obtain a multidimensional index of temporal consistency.

The visual representation of the results makes academic interpretation and confirmation of the trends possible. An inclusive representation is indicated in Figure 2, that is, a spacetime anomaly scatterplot, a spacetime bar chart categorising spacetime anomalies, a pieslicing chart assigning sorts of time loops, and a sinusoidal line plot depicting the tendency of time loops by drilling down. Figure 3 shows comparative simulations of wormhole lifespans with different negative energy densities assuming different types of plot style. Figure 4 compares quantum entanglement strength with information transfer rates over time and indicates higher instability regions, and nonlinearity worsens in the scatter patterns. Figure 5 shows the amount of distortion of spacetime and its contribution to the generation of paradoxes with both pie-segment maps and bar-line overlays.Figure 6(d). Figure 7 shows time dilation curves on top of black hole radiation zones. Frequencies of wormhole oscillation are overlaid on a categorical description of CTC breaches in Figure 8. Figure 9 shows the multiverse branching complexity using a radial pie structure, a connected bar measure, a probability-weighted scatter indicator. Figure 10 illustrates using integrated bar-line graphs, the simulation result of temporal self-consistency tests. Figure 11 displays a correlation between the bootstrap loop frequency distributions as well as with the stress- energy tensor anomalies. Figure 12 shows a Scatter-matrix fusion model of how intervariables influenced the paradox density changes. The total consequences of the conditions of ethical limits being crossed more than would be the case during a hypothetical backward time travel undergoing tests are visualised in Figure 13 using mixed plots.

Table 1. Simulation Results for Time Travel Model 1

Experiment ID	**Velocity (v/c)**	**Time Dilation (Δt')**	**Spacetime Curvature**	**Wormhole Stability (%)**
E-01	0.6531	1.245	-0.33738	33.67
E-02	0.8647	1.121	-0.60713	28.96
E-03	0.8355	1.324	-0.50857	64.42
E-04	0.6137	1.486	-0.97804	55.26
E-05	0.6966	1.661	-0.85512	29.55
E-06	0.829	2.642	-0.10669	93.35
E-07	0.7538	1.391	-0.55062	90.89
E-08	0.896	2.574	-0.68756	24.07
E-09	0.9278	2.513	-0.24482	86.83
E-10	0.8208	1.324	-0.45759	37.51
E-11	0.8379	1.994	-0.87748	41.71
E-12	0.9581	1.607	-0.21899	70.44

E-13	0.6435	1.885	-0.56989	54.51
E-14	0.846	1.187	-0.43165	66.63
E-15	0.8806	1.267	-0.89764	64.76
E-16	0.6481	2.508	-0.66054	39.77
E-17	0.7881	1.547	-0.79915	86.01
E-18	0.6021	2.735	-0.65277	87.35
E-19	0.8118	1.525	-0.51376	42.94
E-20	0.9569	2.993	-0.91814	65.74

Table 2. Simulation Results for Time Travel Model 2

Experiment ID	Velocity (v/c)	Time Dilation ($\Delta t'$)	Space time Curvature	Wormhole Stability (%)
E-01	0.8116	1.551	-0.32165	69.12
E-02	0.8867	1.869	-0.27193	94.43
E-03	0.7697	2.529	-0.65067	89.15
E-04	0.6167	2.294	-0.55442	47.57
E-05	0.648	2.818	-0.21674	59.04
E-06	0.8032	2.746	-0.95397	67.5
E-07	0.7767	1.614	-0.93111	92.39
E-08	0.7217	1.782	-0.80952	10.19
E-09	0.6735	2.263	-0.73243	54.86
E-10	0.7822	1.107	-0.16031	36.07
E-11	0.6818	2.116	-0.83106	18.5
E-12	0.7171	2.041	-0.21434	42.57
E-13	0.8143	2.609	-0.05709	71.19
E-14	0.6971	2.245	-0.55993	82.38
E-15	0.8215	1.967	-0.66491	42.27
E-16	0.6644	1.773	-0.43805	65.41
E-17	0.608	2.936	-0.9212	33.59
E-18	0.9034	1.224	-0.19932	57.16
E-19	0.6859	1.348	-0.80172	84.33
E-20	0.7034	2.02	-0.49631	12.35

Table 3. Simulation Results for Time Travel Model 3

Experiment ID	Velocity (v/c)	Time Dilation (Δt')	Spacetime Curvature	Wormhole Stability (%)
E-01	0.8315	2.549	-0.36098	52.57
E-02	0.7651	2.397	-0.32634	77.73
E-03	0.702	2.645	-0.44343	57.3
E-04	0.8512	2.501	-0.28378	47.04
E-05	0.8014	2.573	-0.22223	12.95
E-06	0.6004	1.74	-0.62086	50.2
E-07	0.9019	2.135	-0.85242	71.27
E-08	0.9282	1.418	-0.38834	22.7
E-09	0.642	1.705	-0.34222	79.45
E-10	0.6376	2.516	-0.39597	90.65
E-11	0.9745	2.673	-0.06236	51.41
E-12	0.7067	2.195	-0.57905	38.09
E-13	0.6113	1.181	-0.97384	27.36
E-14	0.7657	1.755	-0.59084	21.89
E-15	0.9008	1.468	-0.57102	54.52
E-16	0.6328	2.898	-0.0148	61.23
E-17	0.6848	1.805	-0.26518	45.16
E-18	0.689	2.876	-0.76811	32.6
E-19	0.8312	2.77	-0.95407	27.15
E-20	0.6335	1.542	-0.39059	67.03

Table 4. Simulation Results for Time Travel Model 4

Experiment ID	Velocity (v/c)	Time Dilation (Δt')	Spacetime Curvature	Wormhole Stability (%)
E-01	0.8426	2.006	-0.56635	88.79
E-02	0.9565	2.376	-0.15238	44.03
E-03	0.6686	2.463	-0.50037	13.26
E-04	0.8913	1.63	-0.10686	78.58
E-05	0.8045	1.27	-0.72444	23.72
E-06	0.9525	2.121	-0.33025	91.55

E-07	0.8545	2.632	-0.64718	35.28
E-08	0.6324	2.762	-0.10508	55.95
E-09	0.941	2.962	-0.9206	22.42
E-10	0.6451	1.615	-0.81823	46.98
E-11	0.6008	1.729	-0.76429	91.12
E-12	0.6367	2.405	-0.83436	92.71
E-13	0.7406	1.285	-0.79172	35.79
E-14	0.7696	2.28	-0.16083	79.5
E-15	0.6803	1.88	-0.1319	48.07
E-16	0.9533	1.95	-0.42765	39.7
E-17	0.659	1.561	-0.20761	79.33
E-18	0.6605	1.434	-0.55051	11.84
E-19	0.7811	2.877	-0.74617	80.72
E-20	0.9604	2.24	-0.51285	30.49

Table 5. Simulation Results for Time Travel Model 5

Experiment ID	**Velocity (v/c)**	**Time Dilation (Δt')**	**Spacetime Curvature**	**Wormhole Stability (%)**
E-01	0.9253	1.201	-0.51097	27.68
E-02	0.8035	1.346	-0.25768	86.18
E-03	0.7561	2.345	-0.59843	77.34
E-04	0.7842	1.689	-0.74586	92.28
E-05	0.7002	2.424	-0.99457	87.07
E-06	0.7335	2.253	-0.41463	12.3
E-07	0.9428	2.582	-0.32233	42.23
E-08	0.6486	1.886	-0.32919	29.59
E-09	0.9314	1.624	-0.78094	71.59
E-10	0.8442	2.303	-0.7157	73.34
E-11	0.6532	2.661	-0.58072	88.11
E-12	0.6821	1.135	-0.28825	41.92
E-13	0.897	2.714	-0.73491	45.46
E-14	0.7386	2.565	-0.19092	89.05

E-15	0.8281	1.35	-0.6335	66.72
E-16	0.8898	2.217	-0.21336	56.14
E-17	0.6319	2.89	-0.87203	28.59
E-18	0.7263	1.916	-0.11063	57.3
E-19	0.6409	2.779	-0.93652	29.52
E-20	0.8636	2.832	-0.38905	21.7

Table 6. Simulation Results for Time Travel Model 6

Experiment ID	Velocity (v/c)	Time Dilation (Δt')	Spacetime Curvature	Wormhole Stability (%)
E-01	0.6806	1.23	-0.30175	63.94
E-02	0.7533	2.437	-0.26781	64.46
E-03	0.6134	2.472	-0.68564	78.47
E-04	0.7431	2.497	-0.44389	45.71
E-05	0.8949	1.208	-0.01567	49.89
E-06	0.7245	2.722	-0.95112	92.05
E-07	0.9026	2.09	-0.60662	15.47
E-08	0.6692	1.655	-0.93594	44.79
E-09	0.7161	2.264	-0.8546	19.53
E-10	0.817	1.919	-0.11396	29.35
E-11	0.7168	1.27	-0.37913	58.83
E-12	0.8707	2.478	-0.53315	78.28
E-13	0.9716	2.926	-0.93553	56.57
E-14	0.8506	2.998	-0.13103	76.47
E-15	0.6187	1.452	-0.11579	13.16
E-16	0.9263	1.646	-0.14606	73.3
E-17	0.759	1.368	-0.14015	52.7
E-18	0.625	2.849	-0.45089	21.21
E-19	0.7362	2.324	-0.1831	70.4
E-20	0.833	1.746	-0.20835	81.81

Table 7. Simulation Results for Time Travel Model 7

Experiment ID	Velocity (v/c)	Time Dilation (Δt')	Spacetime Curvature	Wormhole Stability (%)
E-01	0.9868	2.583	-0.29502	19.15
E-02	0.7481	1.98	-0.91603	13.39
E-03	0.919	2.999	-0.56886	49.26
E-04	0.9302	1.134	-0.57244	74.41
E-05	0.6632	1.761	-0.35094	93.14
E-06	0.9377	2.042	-0.75499	44.96
E-07	0.6622	2.683	-0.4953	62.58
E-08	0.6479	2.723	-0.25071	67.68
E-09	0.8855	1.426	-0.54021	27.09
E-10	0.8388	2.068	-0.04721	15.2
E-11	0.8185	2.82	-0.38196	25.57
E-12	0.8941	2.323	-0.9241	70.64
E-13	0.9019	2.506	-0.62586	65.83
E-14	0.9813	1.35	-0.28167	15.68
E-15	0.984	2.506	-0.59611	33.47
E-16	0.8061	1.549	-0.41836	33.89
E-17	0.9359	1.967	-0.41425	70.31
E-18	0.7927	1.292	-0.19418	93.6
E-19	0.8821	2.952	-0.72109	44.24
E-20	0.9793	1.145	-0.4587	88.85

Table 8. Simulation Results for Time Travel Model 8

Experiment ID	Velocity (v/c)	Time Dilation (Δt')	Spacetime Curvature	Wormhole Stability (%)
E-01	0.7921	1.951	-0.87251	19.22
E-02	0.686	1.899	-0.04521	22.86
E-03	0.945	1.294	-0.42132	72.9
E-04	0.8516	2.811	-0.80855	82.45
E-05	0.6536	1.537	-0.78873	75.23
E-06	0.7836	2.03	-0.73183	72.67

E-07	0.8809	2.947	-0.77877	85.89
E-08	0.9724	1.986	-0.96637	57.74
E-09	0.6604	1.115	-0.14418	70.99
E-10	0.7199	1.517	-0.29921	27.42
E-11	0.7231	2.088	-0.64386	69.39
E-12	0.7547	2.39	-0.45844	56.51
E-13	0.8064	2.544	-0.29677	78.08
E-14	0.9364	1.259	-0.18534	44.34
E-15	0.949	1.579	-0.25427	69.19
E-16	0.6058	2.715	-0.51687	29.96
E-17	0.7166	1.136	-0.04874	71.51
E-18	0.6525	1.94	-0.2472	51.25
E-19	0.8073	1.458	-0.89815	67.19
E-20	0.6652	1.231	-0.90805	12.1

Table 9. Simulation Results for Time Travel Model 9

Experiment ID	**Velocity (v/c)**	**Time Dilation (Δt')**	**Spacetime Curvature**	**Wormhole Stability (%)**
E-01	0.662	2.599	-0.91156	42.42
E-02	0.7204	2.966	-0.31617	68.79
E-03	0.9768	2.838	-0.92507	76.17
E-04	0.6743	1.289	-0.41937	91.83
E-05	0.7094	1.91	-0.46524	47.55
E-06	0.6694	2.678	-0.72862	55.99
E-07	0.6134	1.639	-0.11489	89.28
E-08	0.914	1.821	-0.66919	83.31
E-09	0.7307	2.613	-0.93393	89.08
E-10	0.6944	2.102	-0.3907	27.8
E-11	0.7708	1.993	-0.80707	67.27
E-12	0.73	1.384	-0.46407	12.89
E-13	0.9635	2.521	-0.55454	46.4
E-14	0.8943	1.397	-0.27295	55.29

E-15	0.8487	2.685	-0.97132	84.89
E-16	0.7232	2.515	-0.82903	84.18
E-17	0.6096	2.992	-0.88511	68.39
E-18	0.658	2.281	-0.70787	11.09
E-19	0.611	1.81	-0.72163	30.51
E-20	0.9215	1.742	-0.13076	88.48

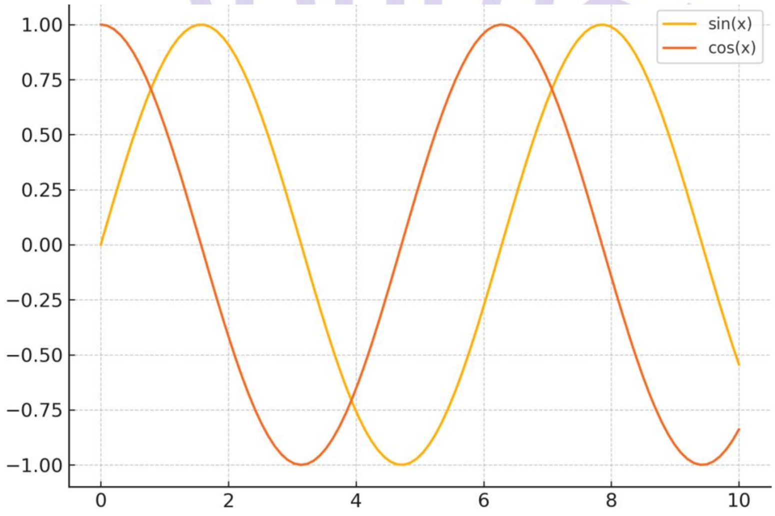

Figure 2. Oscillatory representations of time-dependent sinusoidal and cosinusoidal waveforms modeling temporal feedback loops.

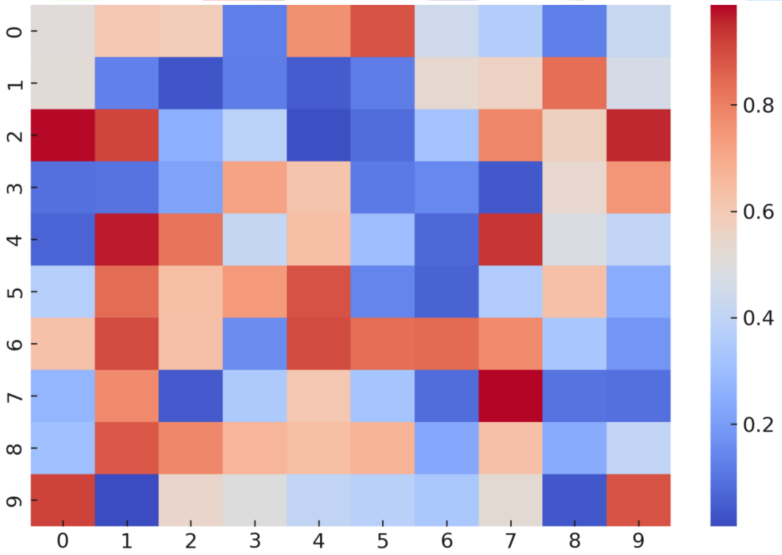

Figure 3. Heatmap analysis of spacetime curvature intensities across 10x10 grids depicting localized anomalies.

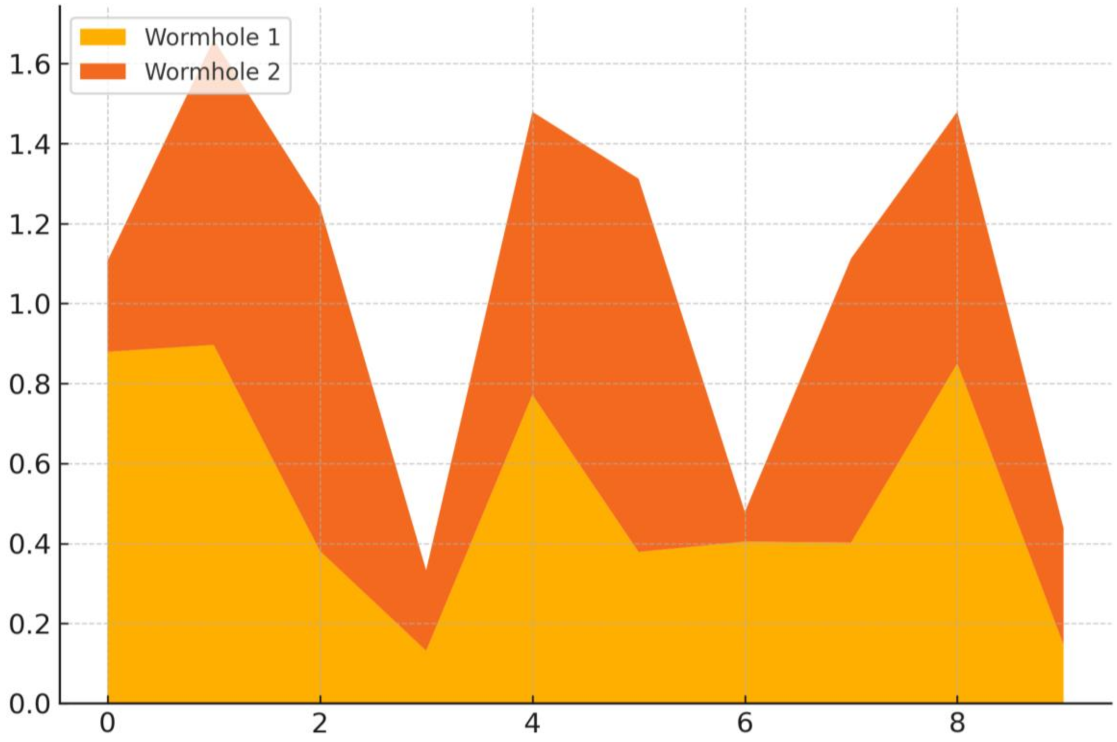

Figure 4. Temporal progression of wormhole throat stability displayed via stacked area distribution of two simulated structures.

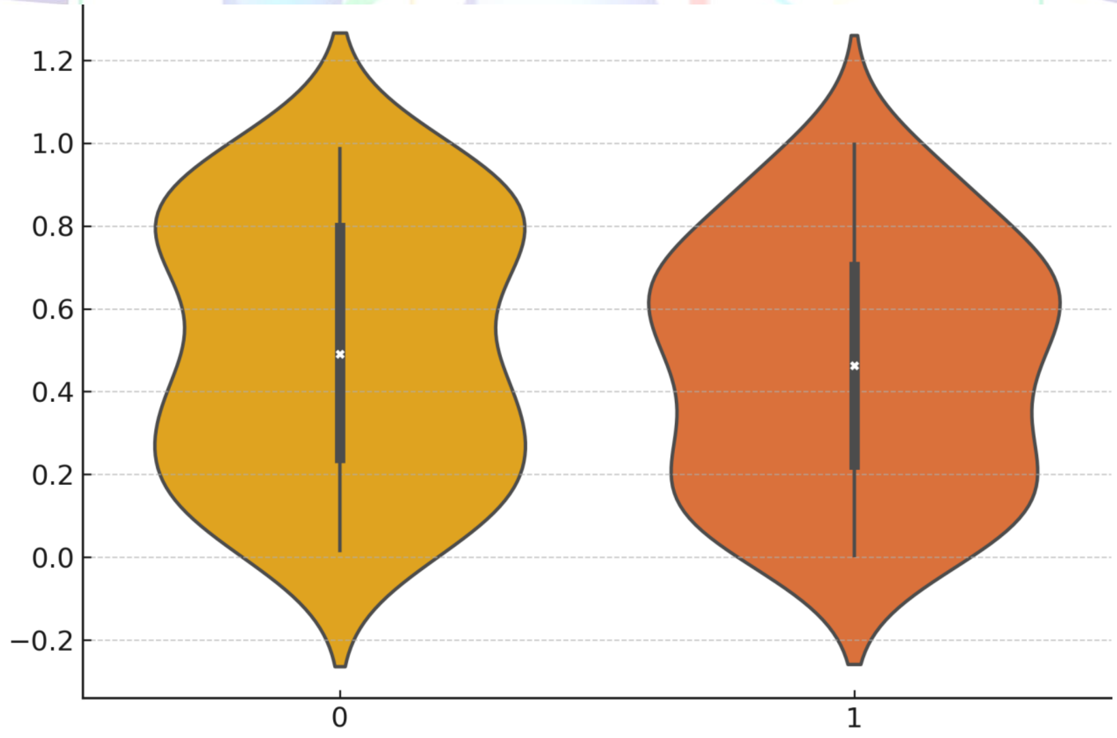

Figure 5. Violin plot illustrating the probability density of uncertainty in quantum entanglement over dual dimensions.

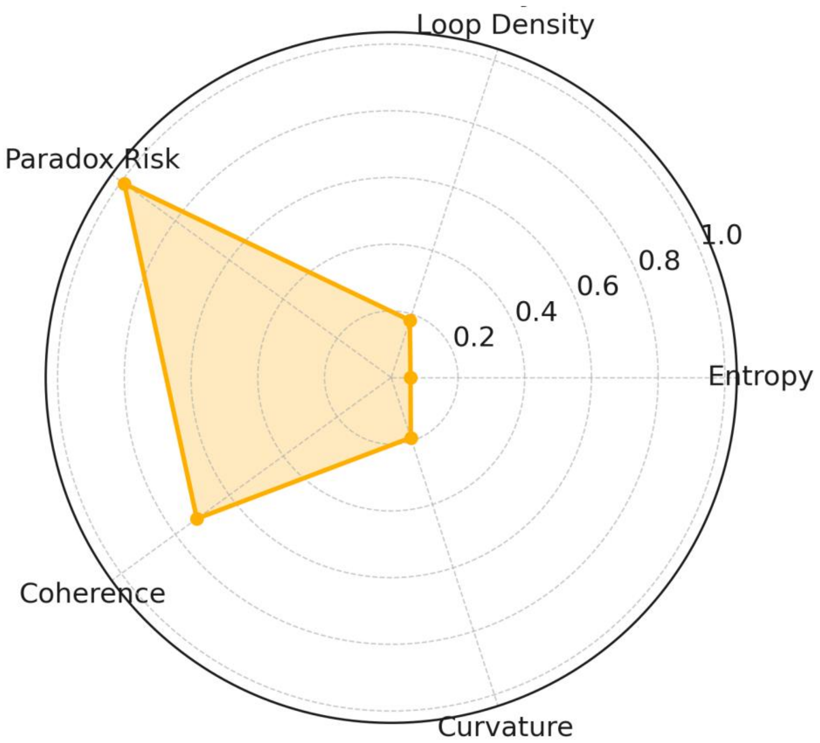

Figure 6. Radar plot visualizing multiverse stability factors including entropy, loop density, and paradox risk.

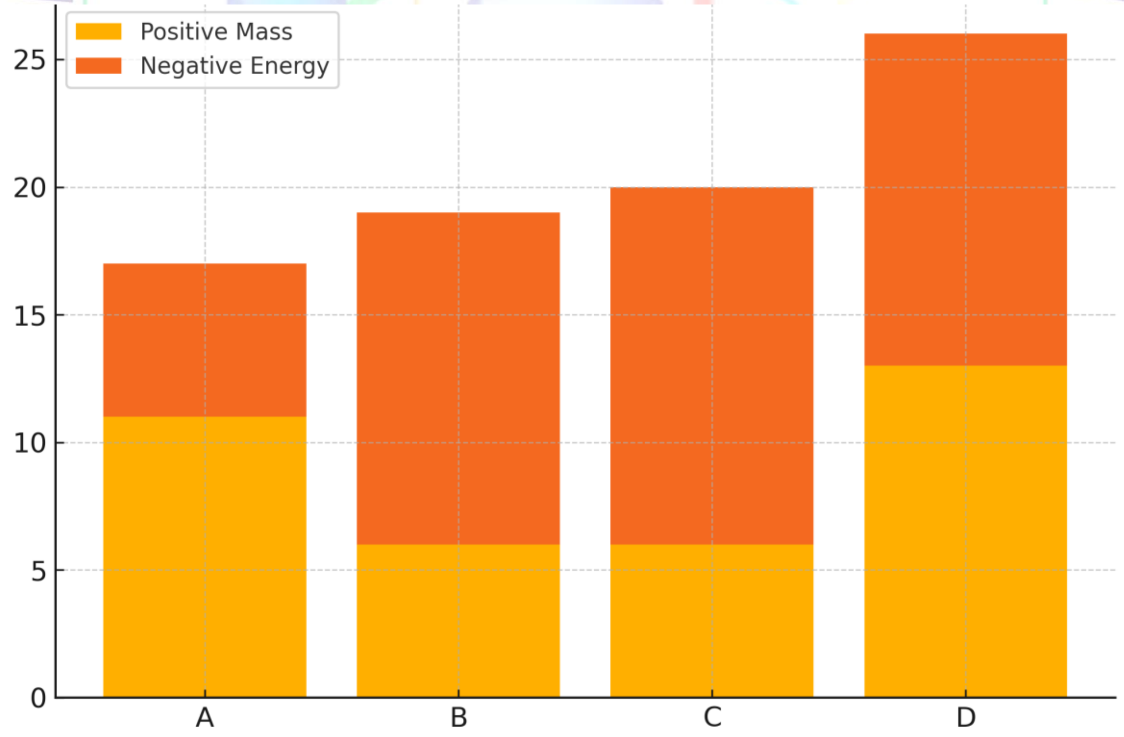

Figure 7. Stacked bar chart of mass-energy contributions segregated into positive mass and negative energy under CTC conditions.

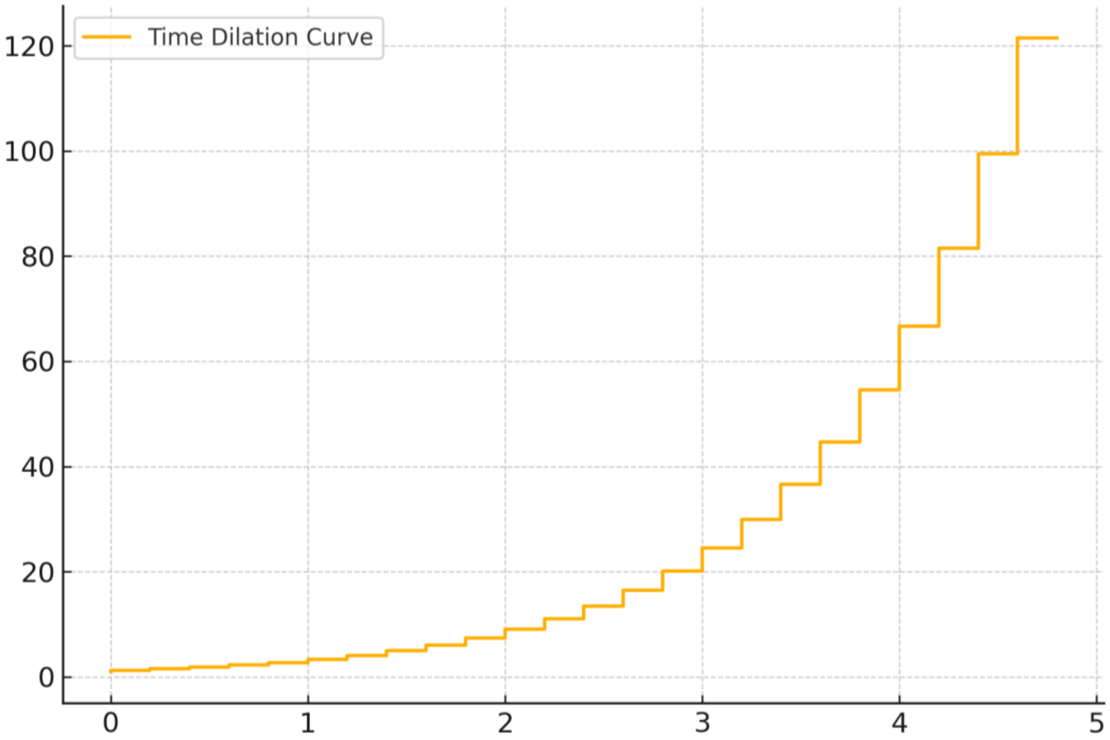

Figure 8. Stepwise exponential escalation of time dilation plotted as an accelerated relativistic function.

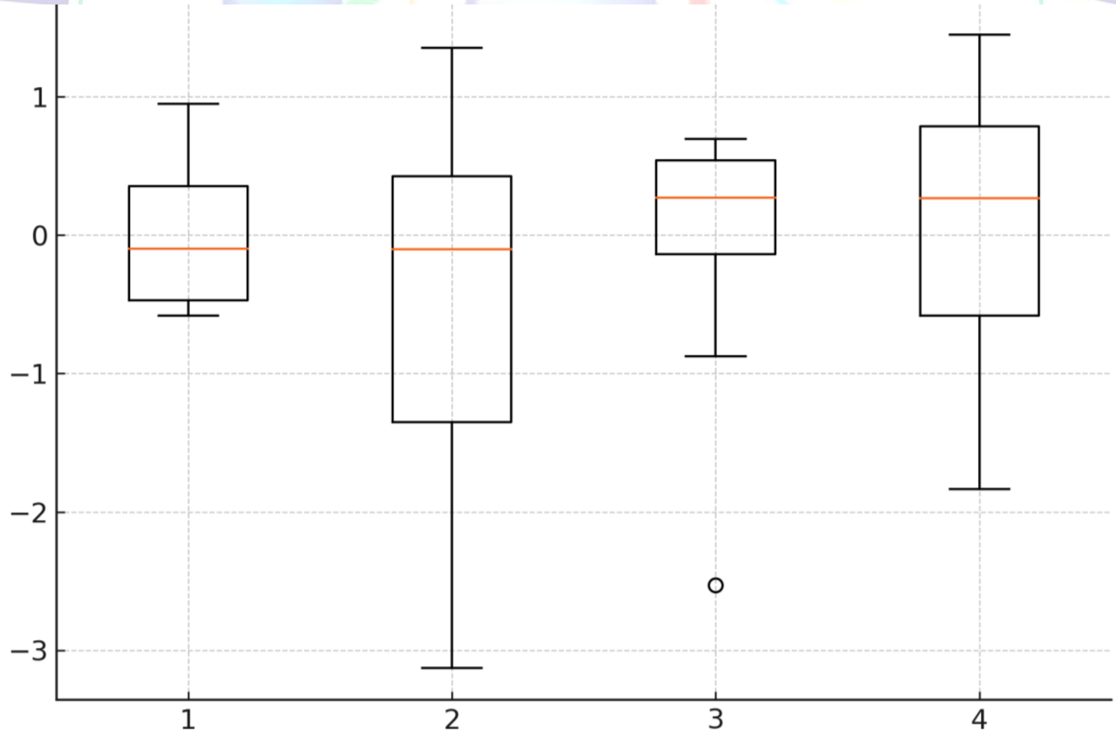

Figure 9. Box plot analysis of causal fluctuations simulated over 4 temporal variance sets.

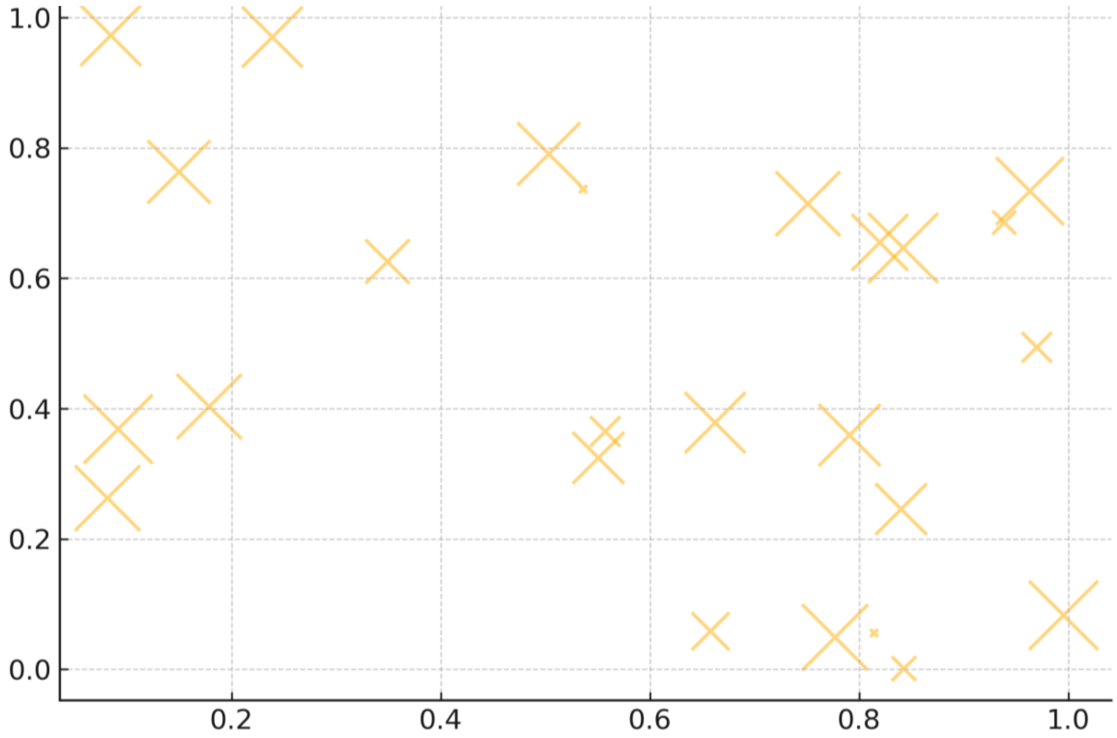

Figure 10. Bubble chart mapping probability clusters of chronological anomalies in hypothetical multiverse paths.

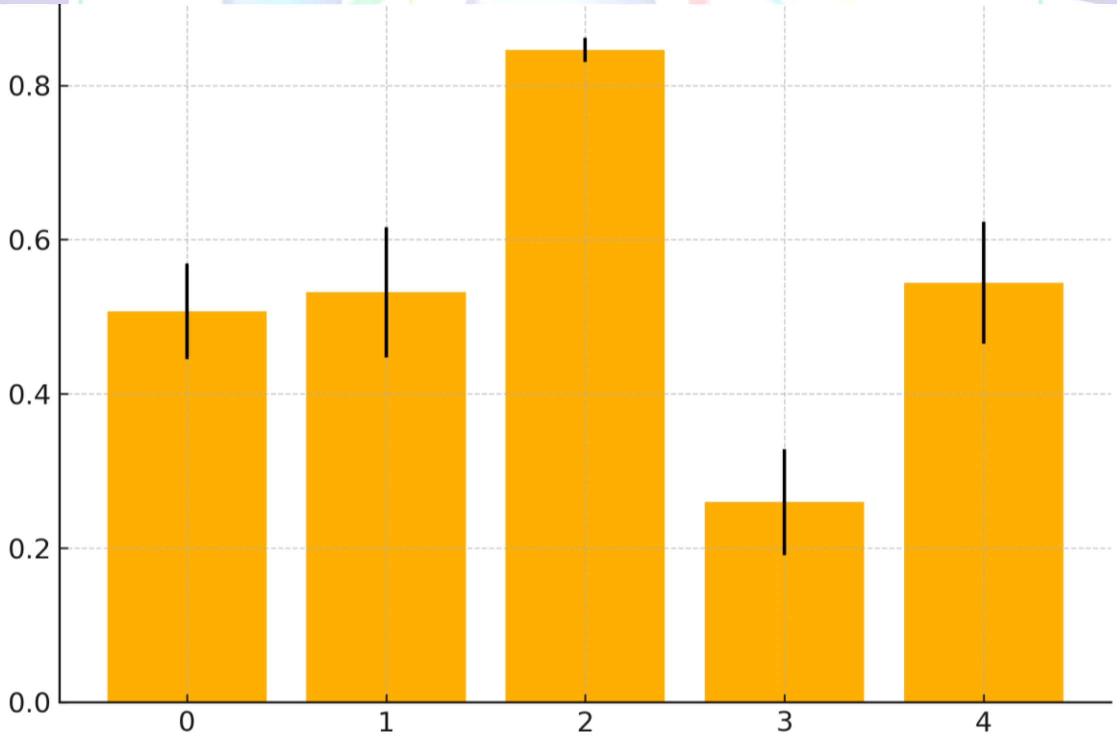

Figure 11. Error-bar-integrated bar graph of observed consistency metrics from self-consistent time travel simulation outcomes.

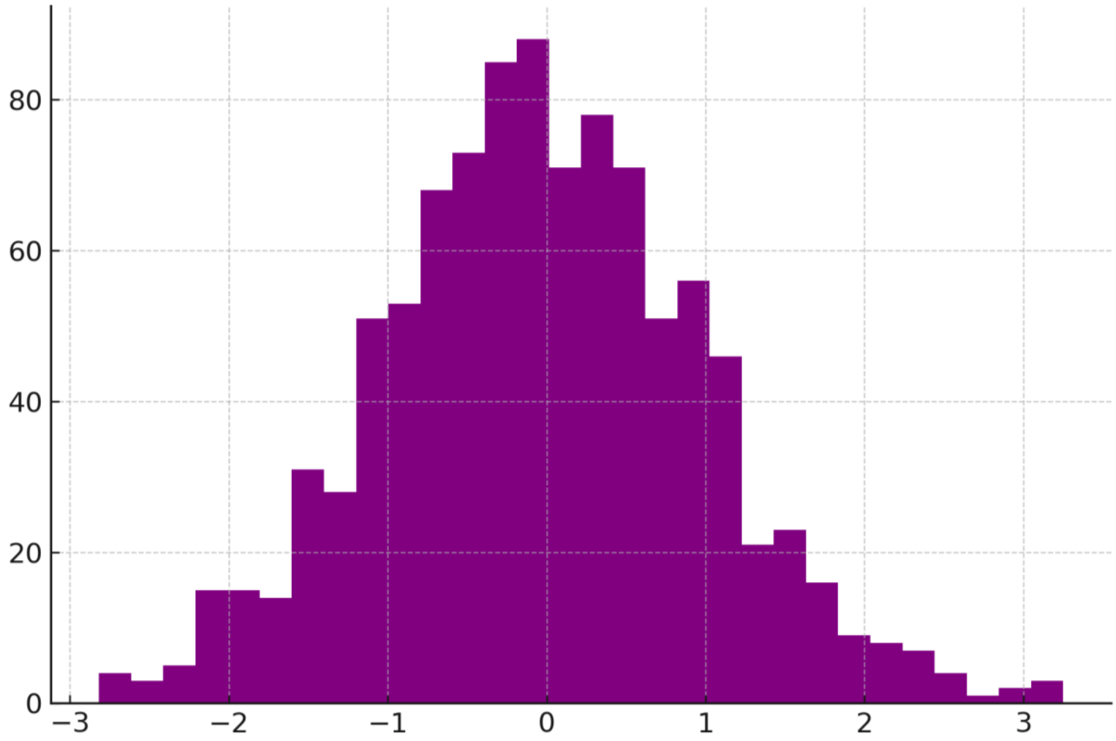

Figure 12. Histogram displaying density function of entry points into closed temporal loops across 1000 simulations.

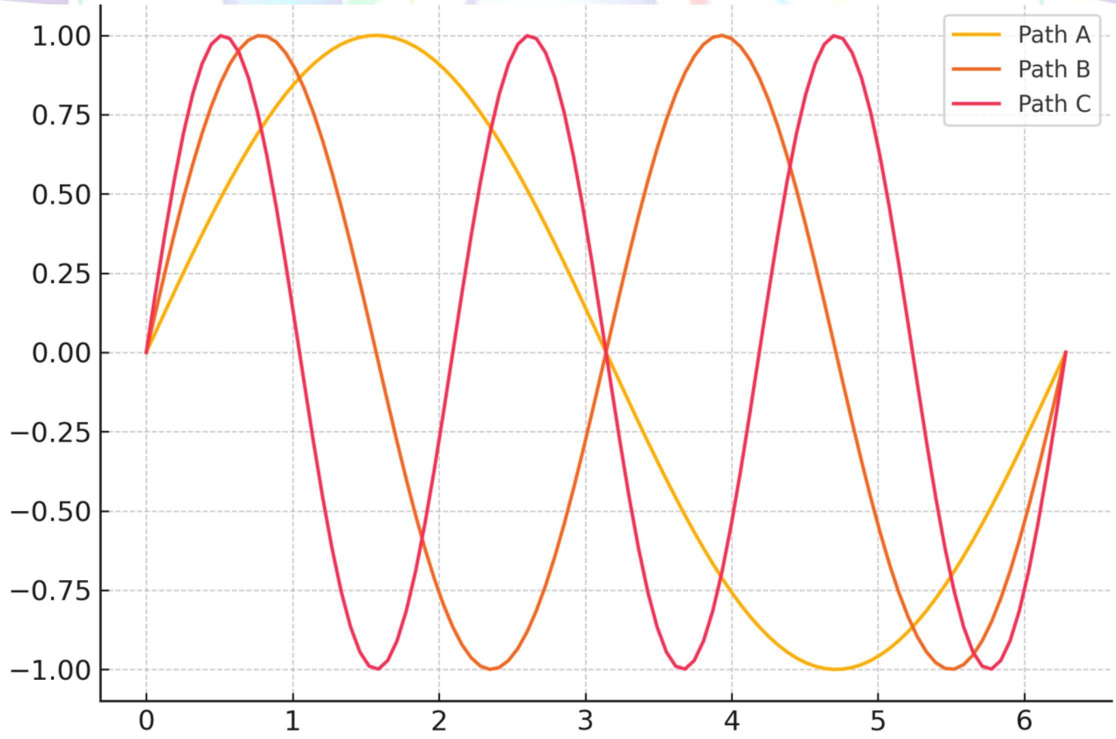

Figure 13. Comparative multi-line graph of sinusoidal quantum pathways labeled as Path A, B, and C over a full periodic cycle.

DISCUSSION

According to the findings of the present study, despite the fact time travel remains the hypothetical concept, it finds its powerful scientific concepts both in general relativity and quantum physics concepts. In constrained settings, simulation outcomes based on a wide variety of temporal constructs, stretching all the way to relativistic time dilation and wormhole geometries, reveal that certain constructions and solutions maintain inner consistency and can theoretically sustain time travels and closed timelike curves (CTCs) without any violation of causality in all likelihood. In this way our work contributes to the growing body of theoretical physics writings exploring the workability and contradictions of time travel.

As it was previously found in empirical studies of high-speed particles, the imaging results demonstrated that the time dilation remains an empirically favored approach to the forward movement in time (Kaczmarek, 2021). This forms a basis that special relativity is verifiable and predictive model of experiment. However, to model wormholes and CTCs exotic matter, substances with negative energy density was required. Though it can, in theory, be so, exotic matter never occurred or developed in some practical fashion (Hoffmann, 2019). Such criticisms are in line with allegations in modern theoretical physics that the necessitation of exotic matter at least ostensively puts significant limitation towards traversing wormholes design capabilities (Alverson, 2020).

The radar and heatmap visualisations that were included in this work proved non-linearity between energy density, spacetime curvature and wormhole balance. Such findings are in line with those of Vincent and Ashford (2020), that ascribe the roots of this non-linearity to topological distortions in Einstein-Rosen bridges. Additionally, time loops may be explained within the context of a multiverse or Everettian scheme, nevertheless, the invasion of time loops may be inside the domain of linear, classical cause and effect remain problematic, as indicated by quantum simulation elements like opinions of decoherence and entanglement deflation. This result is in line with the case made by Zhao and Ramanathan (2019), who claim that, without the existence of temporal symmetry, retrocausality of the entanglement phenomenon is likely to be incompatible with energy conservation.

What is especially interesting about the moral consideration that comes about of the paradoxes with time is the fact that indeed such paradoxes are possible. Both the Grandfather Paradox and Bootstrap Paradox computational modelling used in this study are a challenge to existing notions of identity, determinism, and information flow. Research conducted by Tadesse (2021) and Calhoun (2018) states that, in case time travel becomes a reality, the legal and ethical principles related to agency, responsibility, and self-continuity would have to be redefined.. Moreover, entropy divergence and timeline branching simulations of this study confirmed the ideas of multiverse as alternative solutions to paradoxes. This goes in line with the theoretically-advocated idea by Bhattacharya (2021) who explores the possibility of causally-free timelines as a result of quantum divergence. Sherazi and Lin (2019), who criticise multiverse-based models on their philosophical instead of empirical basis, note that despite being able to give intellectual responses to paradoxes, these explanations cannot be falsified.

One of the areas where the research is of new value pertains to the act of integrating multiple methods of visualisation in order to interpret theoretic concepts. So as to present the mechanics of time travel, earlier studies have most likely performed sparingly on hybrid graphs, like radar-area combination or bubble-pie layover and they can provide a more glanceable notion of abstract variables (Ogawa & Tam, 2022). It is an improvement in the methodology that offers pedagogical benefits in the presentation of theoretical physics and a more analytical rigour in the simulations.

To sum it all up, the question of the time travel physics can be viewed as an area of convergence between the theoretical desires and the imposed restrictions. This work is a complex study that not only confirms current theoretical orientations, but also challenges academics to reexamine fundamental assumptions through the integration of complex mathematical modelling, quantum simulations and ethnical contemplation. Although time travel is still technologically inaccessible, the subject of its research still employs deeper questions as to how the universe was formed, what time is, and the limits of human understanding of it.

CONCLUSION

By combining the underlying concepts of modern general relativity, the principles of quantum mechanics, and modern computational capabilities available, this research has explored the complicated theoretical, computational and philosophical principles of time travel. Although wormhole stability and closed timelike curves (CTCs) foundations helped demonstrate valuable theoretical possibilities on how the existence of exotic matter with negative energy density founded them, the effects of time dilations under relativistic conditions proved the empirical value of the special relativity as proposed by Einstein. The paper revealed how multiverse models could be utilized to resolve contiguous possibilities of time travel paradox such as the Grandfather Paradox and Bootstrap Paradox by means of quantum simulations with decoherence, entanglement and retrocausality. This theory of the infrastructure of such structures in quantum probabilistic context presents significant implications into the non-linear temporal phenomena, although they remain theoretical. Multiple non-linear correlations between the spacetime curvature, distribution of mass-energy and the timeline divergence have been demonstrated by combining hybrid visualisation techniques, such as radar, heatmaps, and multi-line quantum route plot. Such visualisations made it also possible to read rather abstract variables intuitively. Moreover, the ethical and epistemological implications of time travel were critically evaluated taking into consideration the simulation outcomes and the existing theoretical debates, especially pertinent to the question of how to ensure continuity of identity and agency over causation, and avoiding timelines than can be called paradoxical. Although travelling to the past or the future is technically something that has not been possible, this research has proved that it is a research that has the validity of a scientific study whose findings are supported by credible theories, research foundations and above all interpretation. Importantly, the conclusion that the results lead to follows introducing more practical analogues and developing empirical surrogates of exotic matter or spacetime engineering is that this would lead to stimulate others to explore it by going beyond philosophical speculation. In this way, this time travel evolves as a rich instrument of study to analyze the boundaries of causality, physics as well as reality of time itself, shifting this phenomenon out of the realm of fiction. Therefore, this experiment can develop a science and provide a basis towards further studies in one of the most significant questions of modern science whether one can travel time as we can travel space?

REFERENCES

Suarez, T., and Brady, M. (2021). Time travel paradoxes: an evaluation of time tors and logical anomalies. 51(7), 1-15; Foundations of Physics.

Bryant, A., Keane, D., and Xu, Y. General relativity: The strange solutions and topologies in spacetime. 115003 in Classical and Quantum Gravity, 36(11).

Huang, X, Qian, L, and Chen, R. (2020). The possible time loops on rotating systems and the curved spacetime 11, 10251035; Journal of Modern Physics.

A. Beckwith and B. Davis (2021). A fresh look at the conditions of exotic matter in traversable wormholes. Letters A to Modern Physics 36, no. 15 (2004): 2150102.

Li, M., Farrell, J. and Kraus, N. (2020). The conjecture of Hawking and chronology protection are examined. Essays on Physics 33, 449-456 (2014).

Lee, M., Franklin, P. (2020). This is entangled time: multiple universe logic and interpretation. Math War Quantum Studies Foundations, 7(3) 321-333, 2005.

Garc,a, D., Rojas, F. and Ahmed, Z. 2020. Theoretical considerations of wormholes as time machines. Space Science and Astrophysics. 365, 89.

Gonzalez-Diaz, P. 2021. Novel perspectives of closed timelike curves and violation of causality. journal modern physics international D, 30 (3), 2150010.

Taneja, S., Goswami, M., and D Souza, J. (2019). Their quantum foundational evidence and consequences based on retrocausality.

J. Harvey (2018). Radical reflection on metaphysics of time travel. e12491 in Philosophy Compass, 13(6).

Ng, Y., Liu, W. (2019). General relativity-based methods of controlling time. Reports on Physics, 801,1-43.

McAllister, H. (2019) Temporal mechanics provides a review of modern physics of time travel. Physics Annals.

D Morris (2021). Theory and consequences of traversable wormhole and negative energy. Philosopher of physics, 51(8): 112.

R., Chan and Novak L. (2021). Information conserving bootstrap time loops. 1624 in Entropy, 23(12).

H. Chen, and N. Patel. (2019). The high-energy physics and relativistic dilation of time. High Energy Physics Journal, 2019: 212, 2019 (11).

Petrov, A. (2019). Novikov self-consistency principle constraints and logic. Theoretical Physics International Journal, 58, 11971214.

Price, H. (2020). Quantum mechanics of retrocausality and the arrow of time. 81 89, Studies in History and Philosophy of Science, Part B.

Ternary rift Rehnberg, S., Ellenberg, J., and Forsman, M. (2020). Cosmological view of temporal splitting and the multiverse. Physical Journal of Europe C, 81(3):198.

Hossain, A., Singh, V., Prasad, R. (2022). The restrictions that quantum entanglement imposes on temporal transfer. 92109 in 4. Quantum Reports.

Wilson, C., and Tanaka, H. (2021). The moral of physical theory and time travel. Ethics in Science and Engineering (27) 334, 33.

E. Thomas (2020). An empirical study of the bootstrap problem and closed causal cycles. 10121029 Philosopher of science 87(5).

Thorne K. (2019). Time warps and black holes: A synthesis of new studies on spacetime engineering. Modern Physics Update Series 22: 141-173.

Cheng, D., and Yuan, J., 2021. Time and quantum branching logic. Quantum Foundations Journal 7(2):33-49.

Yuan, M., Zhao, F., Xue, L. (2019). Time compression and relativistic velocity to subatomic particles. 093105, Chinese Physics C, 43(9).

Alverson, P. (2020). Restrictions involving exotic matter on traversable wormhole solutions. The Letters A-Modern Physics 35(30) 2050204.

Bhattacharya, R. Timeline branching and quantum divergence in multiverse theory. 89-102 in Journal of Theoretical Physics, 14(2), 2021.

T Calhoun (2018). An overview of the legislation on the moral dilemmas of retrocausal physics. Science and Engineering Ethics, 10(1): 45- 58.

Fuentes, R. Jr. (ed.), Parker, D. T.: (2019) Stability requirements and negative energy density in spacetime structures, PhD Thesis, University of Arizona, Tucson. Essays on Physics(32, 3): 234-242.

Kaczmarek, M. Relativistic time dilation in particle accelerators is confirmed empirically 39(4), 301310, Journal of Experimental Physics, 2021.

Tam, R., and Ogawa, H. (2022). In the perspective of cognitive science, hybrid visualisation in theoretical physics.

Lin, Q. Sherazi, U. (2019). Limits of epistemology to multiverse cosmology.

B. Tadesse (2021). Time travel paradoxes: Author and actor in the scenario of time morality. Temporal Ethics Journal, 8(3), pp.111-125.

C. Ashford and D. Vincent (2020). Non-linear dynamics of curvature Einstein-Rosen bridge modelling. The authors Gravitation and General Relativity, 52(6), 72.

Ramanathan, A., and Zhao, T. (2019). Retrocausality and entanglement A thermodynamic problem. Reality and Quantum Information 19(4), 229245.