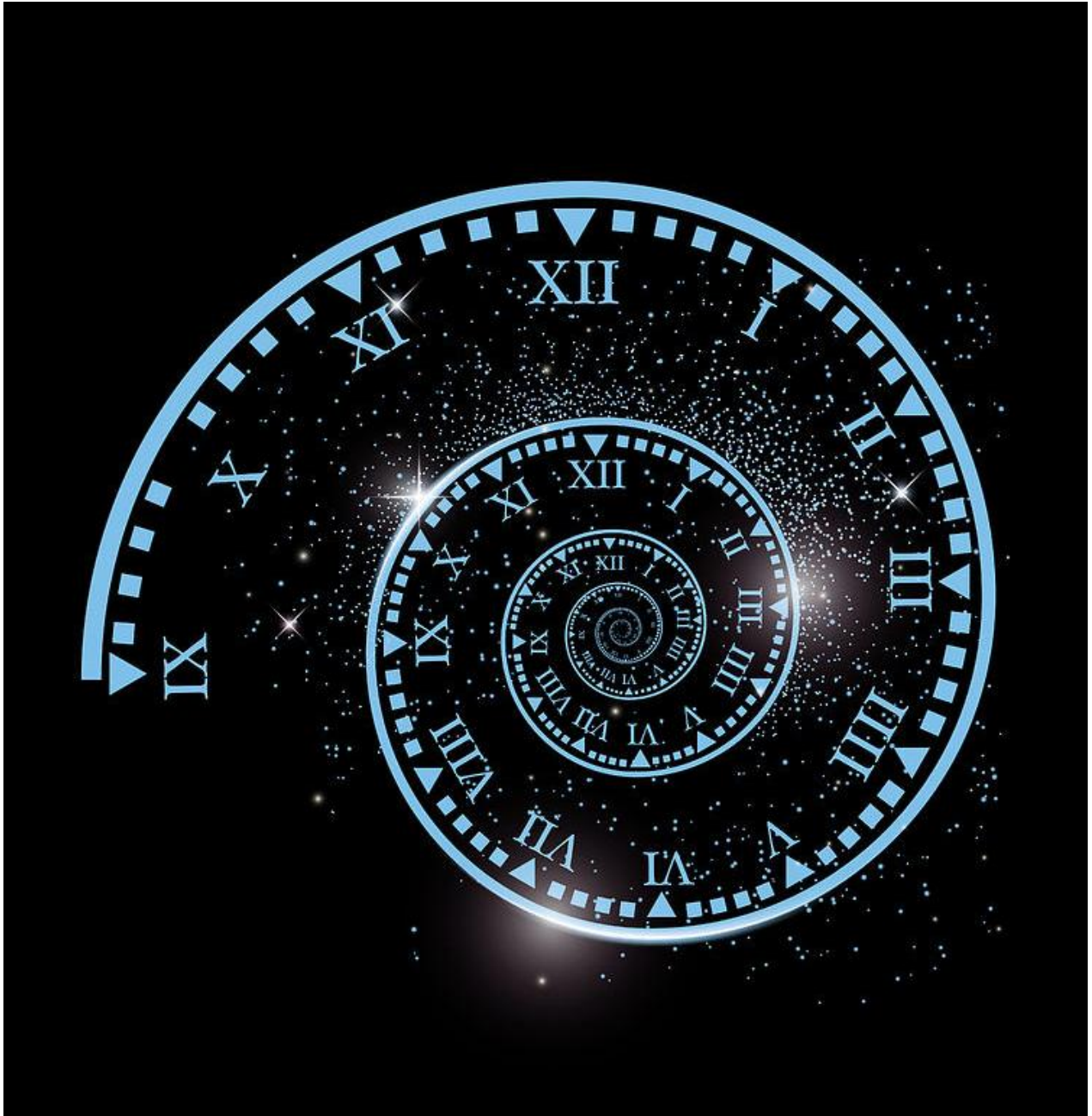


TIME TRAVEL



US official claims America can ‘manipulate time and space’ in bombshell tech reveal

AI, quantum tech, and now... time travel?

Updated: Apr 17, 2025



America just stepped into what sounds like the plot of a science fiction movie.

During a major science and technology conference in Texas, the Trump Administration’s top science official claimed that the United States now possesses technology that can “manipulate time and space” and “leave distance annihilated.”

Michael Kratsios, Director of the White House Office of Science and Technology Policy, made the striking statements on April 14 during his keynote address at the Endless Frontiers Retreat in Austin.

The event brought together government officials, [scientists](#), and business leaders to discuss America's future in innovation.

Kratsios said the U.S. is entering “the early light of the new Golden Age of America,” calling for a renewed national push into advanced technology.

“Our technologies permit us to manipulate time and space,” Kratsios said. “They leave distance annihilated, cause things to grow, and improve productivity.”

He did not clarify whether these claims were literal or metaphorical, but the language has already sparked intense speculation online.

Push to revive mid-century momentum

Throughout his [remarks](#), Kratsios compared current progress to the technological leaps of the 20th century, referencing the Apollo missions, nuclear expansion, and the rise of the internet.

He warned that innovation has slowed in recent decades, hindered by a regulatory system born in the 1970s.

“Advances have not stopped, but something has gone wrong,” Kratsios said. He pointed to a decline in nuclear reactor development, stalled aerospace ambitions, and slower transportation systems as examples of missed opportunities.

He also emphasized the importance of shifting from a reliance on cheap labor and immigration to productivity-enhancing technologies.

“We can build in new ways that let us do more with less,” he said. “Or we can borrow from the future. And we have chosen debt.”

Kratsios described this moment as a turning point, urging the country to “escape the gravity” of the past few decades and re-enter an era of bold invention.

National security, tech diplomacy, and a call to protect innovation

Kratsios also tied technological innovation to U.S. national security and foreign policy. He outlined a three-part strategy to protect American innovation from global competitors — particularly China — by safeguarding intellectual property, securing supply chains, and enforcing export controls.

Time travel might not break the universe after all



A new quantum theory shows that time travel might work—if memory, aging, and entropy reset inside a closed time loop. (CREDIT: CC BY-SA 4.0)© The Brighter Side of News

Time travel has long been a topic of science fiction, filled with thrilling possibilities and mind-bending problems. The most famous of these problems is the "[grandfather paradox](#)". If someone travels to the past and stops their grandfather from having children, they would prevent their own birth—so how could they have made the trip at all?

Until recently, many physicists believed this kind of paradox made time travel impossible. But new research is challenging that view by exploring what happens when a closed system, like a spaceship, loops back in time. Instead of breaking the laws of physics, it may follow them in surprising ways.

A recent study from [Vanderbilt University](#), led by physicist Lorenzo Gavassino, dives deep into the science of time loops using quantum mechanics, thermodynamics, and general relativity. The results suggest that not only might time travel be logically consistent, but the universe could even reset certain aspects of reality—like memory and aging—inside a time loop.

What Closed Timelike Curves Tell Us About Time

[Einstein's general theory of relativity](#), finished in 1915, changed how scientists think about time. It showed that space and time form a flexible fabric that can bend and twist depending on the mass and energy around it. One wild result of this is the possibility of closed timelike curves, or CTCs—paths through space-time that loop back to the same point.

Illustration depicting the Grandfather Paradox. (CREDIT: CC BY-SA 4.0)© The Brighter Side of News

If an object follows a CTC, it could end up where—and when—it started. A spaceship flying on such a loop might revisit a moment in its own past. While this may not happen in our universe on a large scale, areas near spinning black holes could allow for these time loops to form.

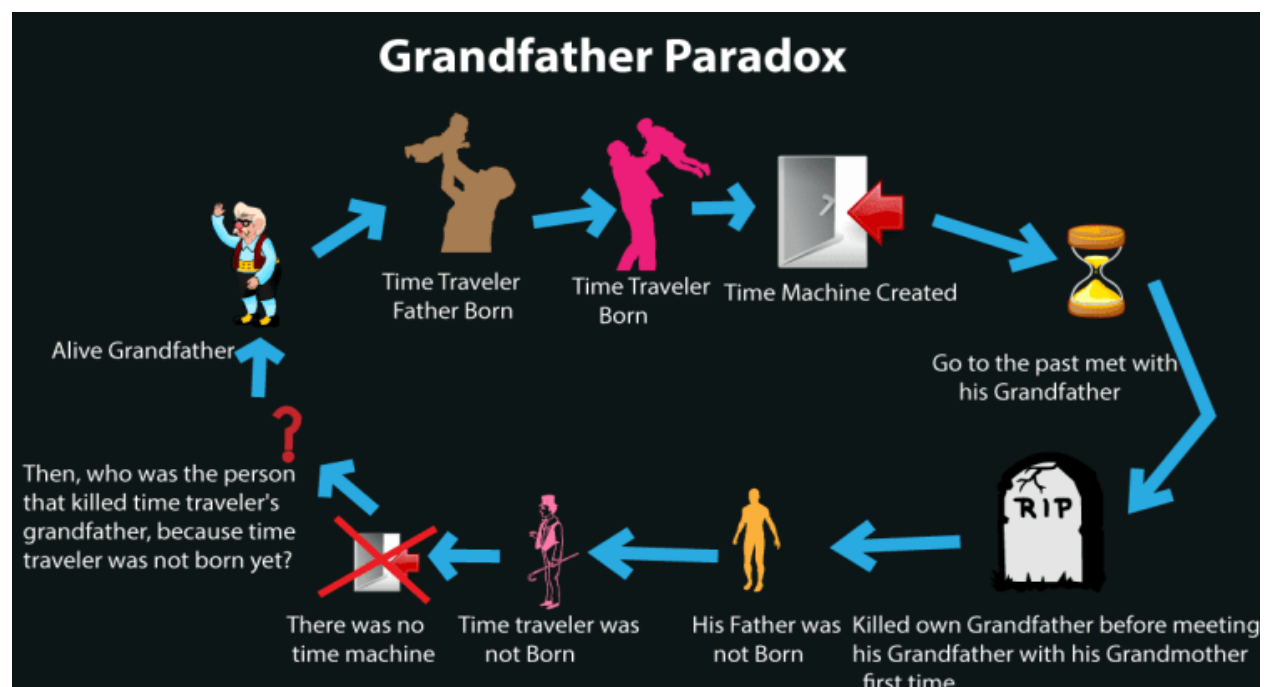


Illustration depicting the Grandfather Paradox. (CREDIT: CC BY-SA 4.0)© The Brighter Side of News

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Physicist Lorenzo Gavassino explored this idea further by studying how a spaceship might behave if it traveled on a CTC in a rotating universe. His study, published in the journal [Classical and Quantum Gravity](#), focused on a specific kind of curve where angular momentum (a kind of rotational energy) drives the journey through time.

Using quantum statistical mechanics, he proved that energy levels inside the spaceship must be finely tuned, locking into specific values. This quantum feature, known as spontaneous discretization, ensures that the spaceship returns to its exact original state after the loop. That includes not just location but also internal systems, like passengers' memories.

This is no ordinary round trip. Once the spaceship completes the loop, everything inside resets to the beginning. That means any change—like aging or forming memories—must disappear. According to Gavassino, “Entropy increase is the reason why we die. What happens when you invert death?”

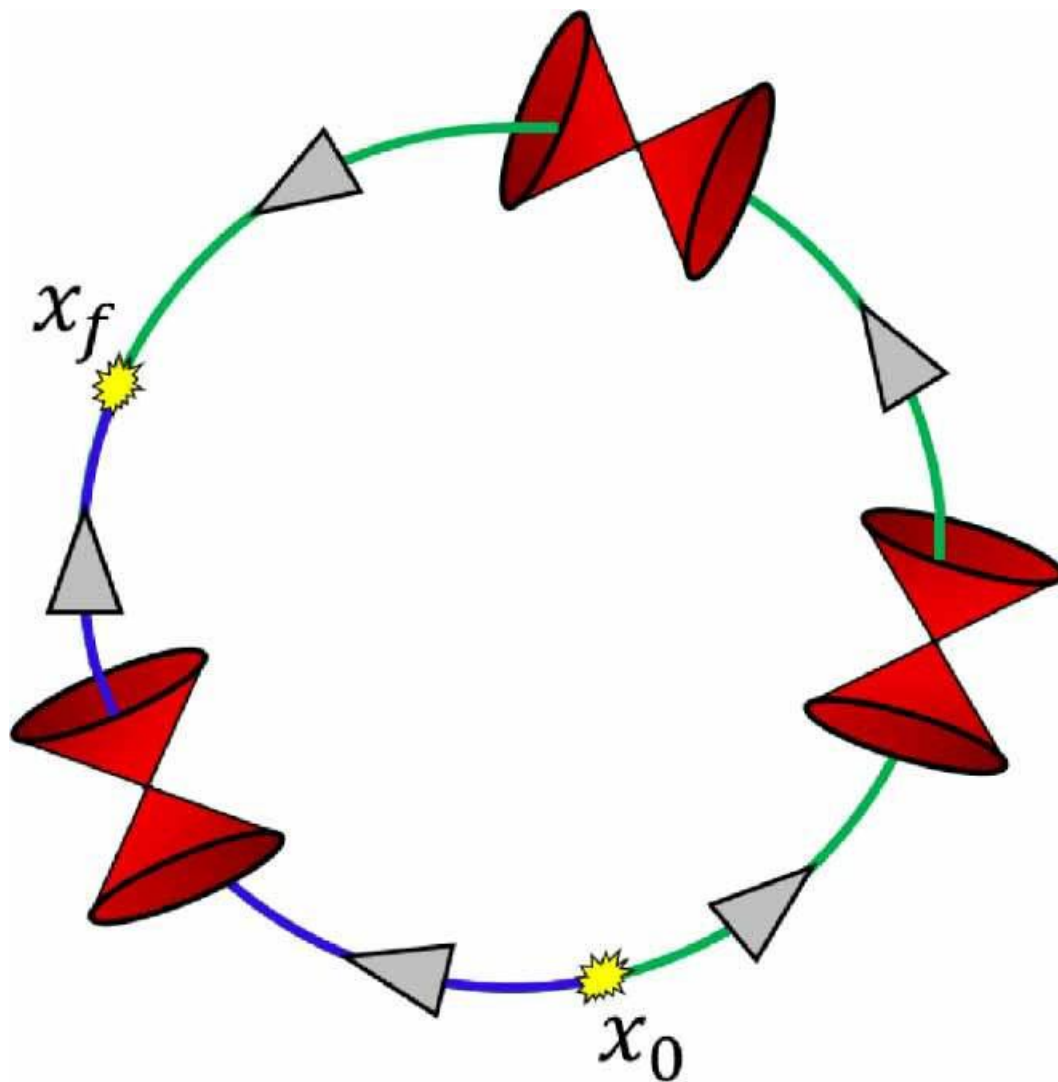
Entropy: Time’s One-Way Street

Entropy is a measure of disorder in a system. When ice melts, when metal rusts, or when people age, entropy increases. It's the reason we experience time moving forward. In fact, it's the only physical law that clearly separates the past from the future.

Normally, entropy can only grow. That’s why we remember the past but can’t predict the future. Our brains, cells, and bodies all rely on this [growth of entropy](#) to function.

But what happens to entropy in a time loop? Gavassino applied a detailed thermodynamic model to explore this. He showed that if a spaceship is thermally

isolated—meaning it doesn't exchange heat with anything outside—it would still follow the rules of entropy, but in a surprising way.



Entropic arrow of time (gray arrows) along a CTC. The positive sense of the arrows follows entropy increase. (CREDIT: Classical and Quantum Gravity)© The Brighter Side of News

Since a loop must return to its starting point, entropy must also reset. This means that there is a lowest point of entropy somewhere on the curve, and a highest point on the opposite side. If you break the loop into two parts, entropy increases in both directions until it reaches the top. After that, everything reverses.

This reversal flips not just physical processes but also biological ones—like aging and memory. The effect? A person could live forward in one half of the loop and backward in the other. Their story would effectively end at the highest-entropy

point, only to begin again in reverse, as though time had split into two mirrored timelines.

In this view, a closed timelike curve isn't just a circle in time—it's more like two entropic arrows pointing from the lowest to the highest point. The same person could exist on both sides but in opposite directions.

No Paradoxes Required

The biggest fear with [time travel](#) is the paradox. How can events be consistent if someone changes the past? Gavassino tackles this using a concept from physics called the self-consistency principle. This rule says that if time travel is real, then only histories that are logically consistent can happen. No grandfather-killing allowed.

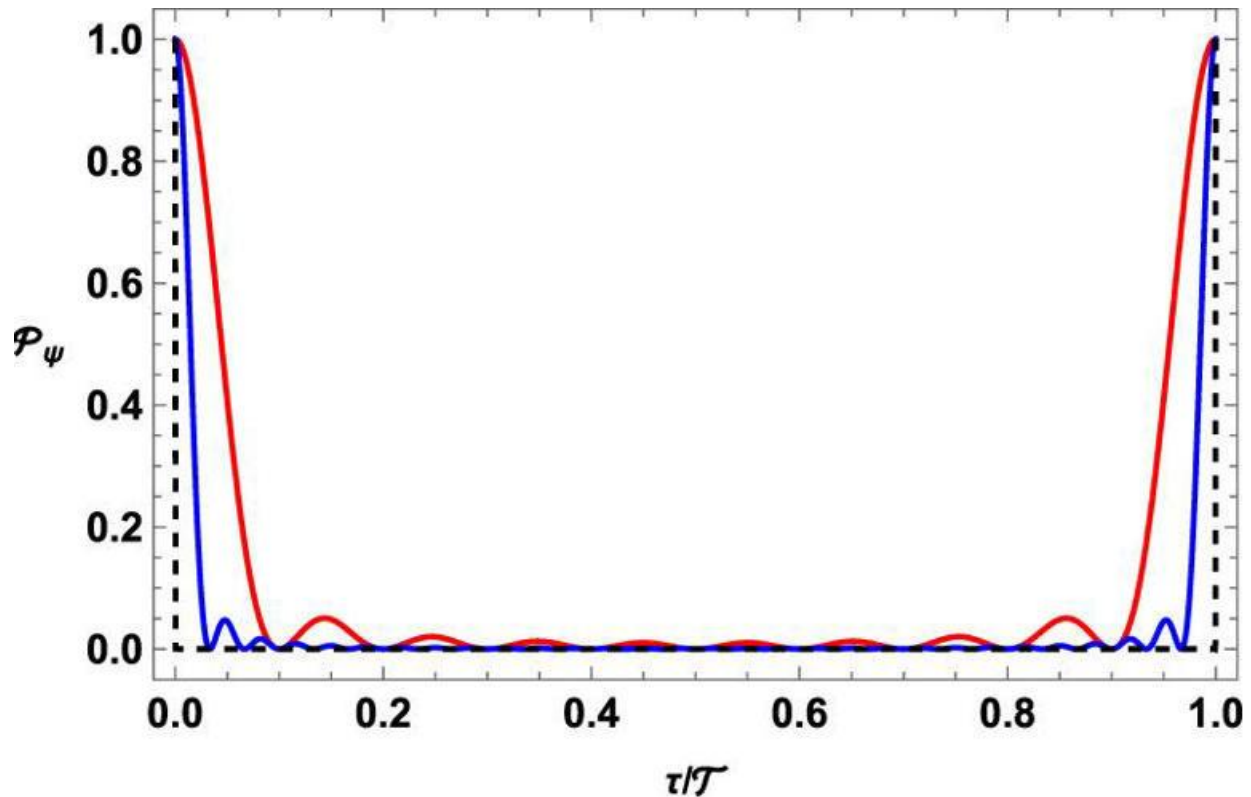
What's exciting about Gavassino's work is that he doesn't just assume this principle—he derives it using Wigner's theorem from quantum mechanics. This theorem shows that in quantum systems, the evolution of states must be consistent. That means if you start in one state, evolve through a loop, and come back, the state must match exactly.

He gives a simple example. Imagine Alice flies in the spaceship, carrying a coin and a notebook. One version of her flips the coin and writes "H" for heads. Another version flips the coin and writes "T" for tails. When they meet at the end of the loop, both versions must agree on what's written. The [universe](#) won't allow contradictions.

In the quantum world, this kind of consistency is automatic. There's no need for extra rules or strange forces. The evolution of the system takes care of it on its own.

Quantum Fluctuations and Time Loops

One key feature of Gavassino's model is the role of [quantum fluctuations](#). These tiny changes in energy and position happen at the smallest scales and are usually random. But on a time loop, they take on a new importance.



Spontaneous decay and later recombination of an unstable particle traveling on a CTC. (CREDIT: Classical and Quantum Gravity)© The Brighter Side of News

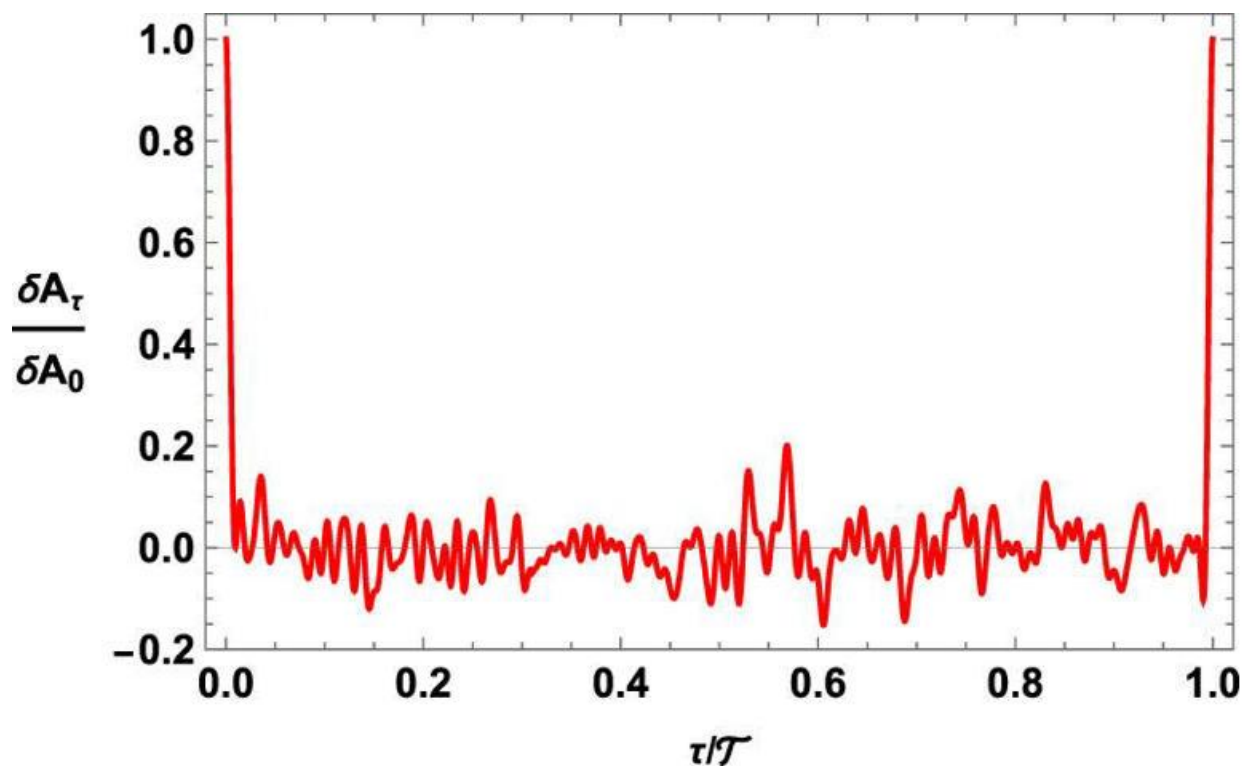
Fluctuations that would normally increase entropy instead cancel it out. That helps return the system to its original state. This smoothing effect means that no matter how messy things get inside the loop, they must tidy themselves up before the loop closes.

This also supports the [eigenstate thermalization hypothesis](#), which says that large quantum systems naturally evolve toward equilibrium in a predictable way. Even on a time loop, the system must eventually cool back down, erase the mess, and reset to its earlier state.

So if you met your younger self on a time loop, you might not remember it. Your memory could be wiped as entropy resets. And if you tried to change something, it wouldn't stick. Events must line up in a way that avoids contradiction.

As Gavassino puts it, "Most physicists and philosophers have argued that if time travel exists, nature will always find a way to prevent contradictory situations."

His work now offers a rigorous proof of that idea, using only accepted [principles of physics](#). There's no need for extra assumptions or strange loopholes.



Numerical evolution of a generic quantity A in a thermodynamic system that fulfills the eigenstate thermalization hypothesis and travels along a CTC. (CREDIT: Classical and Quantum Gravity)© The Brighter Side of News

Is Time Travel Real?

While this theory opens the door for time loops to make sense, it doesn't mean time machines are coming soon. Most scientists still believe that CTCs may be blocked by nature.

In fact, Stephen Hawking proposed a "chronology protection conjecture" in 1992. He suggested that the laws of physics prevent time loops from forming, possibly by creating singularities—breakdowns in space-time—whenever a loop tries to appear.

But even if time travel stays theoretical, Gavassino's work has value. It helps scientists understand entropy, [memory](#), and the behavior of complex systems in extreme conditions.

“What I find interesting about this topic,” Gavassino said, “is the way it forces us to think about the role of entropy in generating our experience of the universe.”

Thinking through these questions helps physicists probe the edges of what’s possible. It also sheds light on real systems, like black holes or [subatomic particles](#), where time may behave in strange ways.

For now, you can’t build a time machine. But if your future self sends you the plans, at least there’s a theory to explain how it all fits together.

Time Travel and Modern Physics

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Time travel has been a staple of science fiction. With the advent of general relativity, it has been entertained by serious physicists. But, especially in philosophy literature, there have been arguments that time travel is inherently paradoxical. The most famous paradox is the grandfather paradox: you travel back in time and kill your grandfather, thereby preventing your existence. To avoid inconsistency some circumstance will have to occur which makes you fail in this attempt to kill your grandfather. Doesn’t this require some implausible constraint on otherwise unrelated circumstances? We examine such worries in the context of modern physics.

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- [2. Topology and Constraints](#)
- [3. The General Possibility of Time Travel in General Relativity](#)
- [4. Two Toy Models](#)
- [5. Slightly More Realistic Models of Time Travel](#)
- [6. The Possibility of Time Travel Redux](#)
- [7. Even If There are Constraints, So What?](#)
- [8. Computational Models](#)
- [9. Quantum Mechanics to the Rescue?](#)

- ## 10. Conclusions

1. Paradoxes Lost?

Modern physics strips away many aspects of the manifest image of time. Time as it appears in the equations of classical mechanics does not need a distinguished present moment, for example. Relativity theory leads to even sharper contrasts. It replaces absolute simultaneity, according to which it is possible to unambiguously determine the time order of distant events, with relative simultaneity: extending an “instant of time” throughout space is not unique but depends on the state of motion of an observer. More dramatically, in general relativity, the mathematical properties of time (or better, of spacetime)—its topology and geometry—depend upon how matter is arranged rather than being fixed once and for all. So, physics can be and indeed has to be formulated without treating time as a universal, fixed background structure. Since general relativity represents gravity through spacetime geometry, the allowed geometries must be as varied as how matter can be arranged. Alongside geometrical models used to describe the solar system, black holes, and much else, the scope of variation extends to include some exotic structures unlike anything astrophysicists have observed. In particular, there are spacetime geometries with curves that loop back on themselves: closed time-like curves (CTCs), which describe the possible trajectory of an observer who returns exactly back to their earlier state—without any funny business, such as going faster than the speed of light. These geometries satisfy the relevant physical laws, and the equations of general relativity, and in that sense time travel is physically possible.

Yet circular time generates paradoxes, familiar from science fiction stories featuring time travel:

Consistency: Kurt plans to murder his own grandfather, Adolph, by traveling along a CTC to an appropriate moment in the past. He is an able marksman and waits until he has a clear shot at Grandpa. Normally he would not miss. Yet if he succeeds, there is no way that he will then

exist to plan and carry out the mission. Kurt pulls the trigger: what can happen?

Underdetermination: Suppose that Kurt first travels back to give his earlier self a copy of *How to Build a Time Machine*. This is the same book that allows him to build a time machine, which he then carries with him on his journey to the past. Who wrote the book *Easy Knowledge: A Fan of Classical Music Enhances their Computer with a Circuit that Exploits a CTC?* This machine efficiently solves problems at a higher level of computational complexity than conventional computers, leading (among other things) to finding the smallest circuits that can generate Bach's oeuvre—and to compose new pieces in the same style. Such easy knowledge is at odds with our understanding of our epistemic predicament. (This third paradox has not drawn as much attention.)

The first two paradoxes were once routinely taken to show that solutions with CTCs should be rejected—with charges varying from violating logic, to being “physically unreasonable”, to undermining the notion of free will. Closer analysis of the paradoxes has largely reversed this consensus. Physicists have discovered many solutions with CTCs and have explored their properties in pursuing foundational questions, such as whether physics is compatible with the idea of objective temporal passage (starting with Gödel 1949). Philosophers have also used time travel scenarios to probe questions about, among other things, causation, modality, free will, and identity (see, e.g., Earman 1972 and Lewis's seminal 1976 paper).

We begin below with *Consistency*, turning to the other paradoxes in later sections. A standard, stone-walling response is to insist that the past cannot be changed, as a matter of logic, even by a time traveler (e.g., Gödel 1949, Clarke 1977, Horwich 1987). Adolph cannot either die and survive, as a matter of logic, so any scheme to alter the past must fail. In many of the best time travel fiction, the actions of a time traveler are constrained in novel and unexpected ways. Attempts to change the past fail, and they fail, often tragically, in just such a way that they set the stage for the time traveler's self-defeating journey. The first question is

whether there is an analog of the consistent story when it comes to physics in the presence of CTCs. As we will see, there is a remarkable general argument establishing the existence of consistent solutions. Yet a second question persists: why can't time-traveling Kurt kill his grandfather? Doesn't the necessity of failures to change the past put unusual and unexpected constraints on time travelers or objects that move along with CTCs? The same argument shows that there are no constraints imposed by the existence of CTCs, in some cases. After discussing this line of argument, we will turn to the palatability and further implications of such constraints if they are required and then turn to the implications of quantum mechanics.

2. Topology and Constraints

Wheeler and Feynman (1949) were the first to claim that the fact that nature is continuous could be used to argue that causal influences from later events to earlier events, as are made possible by time travel, will not lead to paradox without the need for any constraints. Maudlin (1990) showed how to make their argument precise and more general and argued that nonetheless, it was not completely general.

Imagine the following setup. We start off having a camera with a black and white film ready to take a picture of whatever comes out of the time machine. An object, in fact, a developed film, comes out of the time machine. We photograph it and develop the film. The developed film is subsequently put in the time machine and set to come out of the time machine at the time the picture is taken. This surely will create a paradox: the developed film will have the opposite distribution of black, white, and shades of gray, from the object that comes out of the time machine. Developed black and white films (i.e., negatives) have the opposite shades of gray from the objects they are pictures of. But since the object that comes out of the time machine is the developed film itself we surely have a paradox.

However, it does not take much thought to realize that there is no paradox here. What will happen is that a uniformly gray picture will emerge, which produces a developed film that has exactly the same

uniform shade of gray. No matter what the sensitivity of the film is, as long as the dependence of the brightness of the developed film depends in a continuous manner on the brightness of the object being photographed, there will be a shade of gray that, when photographed, will produce exactly the same shade of gray on the developed film. This is the essence of Wheeler and Feynman's idea. Let us first be a bit more precise and then a bit more general.

For simplicity let us suppose that the film is always a uniform shade of gray (i.e., at any time the shade of gray does not vary by location on the film). The possible shades of gray of the film can then be represented by the (real) numbers from 0, representing pure black, to 1, representing pure white.

Let us now distinguish various stages in the chronological order of the life of the film. In stage S1S1 the film is young; it has just been placed in the camera and is ready to be exposed. It is then exposed to the object that comes out of the time machine. (That object in fact is a later stage of the film itself). By the time we come to stage S2S2 of the life of the film, it has been developed and is about to enter the time machine. Stage S3S3 occurs just after it exits the time machine and just before it is photographed. Stage S4S4 occurs after it has been photographed and before it starts fading away. Let us assume that the film starts out in stage S1S1 in some uniform shade of gray, and that the only significant change in the shade of gray of the film occurs between stages S1S1 and S2S2. During that period, it acquires a shade of gray that depends on the shade of gray of the object that was photographed. In other words, the shade of gray that the film acquires at stage S2S2 depends on the shade of gray it has at stage S3S3. The influence of the shade of gray of the film on stage S3S3, on the shade of gray of the film at stage S2S2, can be represented as a mapping, or function, from the real numbers between 0 and 1 (inclusive), to the real numbers between 0 and 1 (inclusive). Let us suppose that the process of photography is such that if one imagines varying the shade of gray of an object in a smooth, continuous manner then the shade of gray of the

developed picture of that object will also vary in a smooth, continuous manner. This implies that the function in question will be a continuous function. Now any continuous function from the real numbers between 0 and 1 (inclusive) to the real numbers between 0 and 1 (inclusive) must map at least one number to itself. One can quickly convince oneself of this by graphing such functions. For one will quickly see that any continuous function f from $[0,1]$ to $[0,1]$ must intersect the line $y=x$ somewhere, and thus there must be at least one point x such that $f(x)=x$. Such points are called fixed points of the function. Now let us think about what such a fixed point represents. It represents a shade of gray such that when photographed, it will produce a developed film with exactly that same shade of gray. The existence of such a fixed point implies a solution to the apparent paradox.

Let us now be more general and allow color photography. One can represent each possible color of an object (of uniform color) by the proportions of blue, green and red that make up that color. (This is why television screens can produce all possible colors.) Thus one can represent all possible colors of an object by three points on three orthogonal lines x , y , and z , that is to say, by a point in a three-dimensional cube. This cube is also known as the “Cartesian product” of the three-line segments. Now, one can also show that any continuous map from such a cube to itself must have at least one fixed point. So, color photography cannot be used to create time travel paradoxes either! Even more generally, consider some system PP which, as in the above example, has the following life. It starts in some state S_1 , it interacts with an object that comes out of a time machine (which happens to be its older self), it travels back in time, it interacts with some object (which happens to be its younger self), and finally, it grows old and dies. Let us assume that the set of possible states of PP can be represented by a Cartesian product of n closed intervals of the reals, i.e., let us assume that the topology of the state-space of PP is isomorphic to a finite Cartesian product of closed intervals of the reals. Let us further assume

that the development of PP in time, and the dependence of that development on the state of objects that it interacts with, is continuous. Then, by a well-known fixed point theorem in topology (see, e.g., Hocking & Young 1961: 273), no matter what the nature of the interaction is, and no matter what the initial state of the object is, there will be at least one state S_3S_3 of the older system (as it emerges from the time travel machine) that will influence the initial state S_1S_1 of the younger system (when it encounters the older system) so that, as the younger system becomes older, it develops exactly into state S_3S_3 . Thus, without imposing any constraints on the initial state S_1S_1 of the system PP, we have shown that there will always be perfectly ordinary, non-paradoxical, solutions, in which everything that happens, happens according to the usual laws of development. Of course, there is looped causation, hence presumably also a looped explanation, but what do you expect if there is looped time?

Unfortunately, for the fans of time travel, a little reflection suggests that there are systems for which the needed fixed-point theorem does not hold. Imagine, for instance, that we have a dial that can only rotate in a plane. We are going to put the dial in the time machine. Indeed, we have decided that if we see the later stage of the dial come out of the time machine set at angle xx , then we will set the dial to $x+90$, and throw it into the time machine. Now it seems we have a paradox, since the mapping that consists of a rotation of all points in a circular state-space by 90 degrees does not have a fixed point. And why wouldn't some state spaces have the topology of a circle?

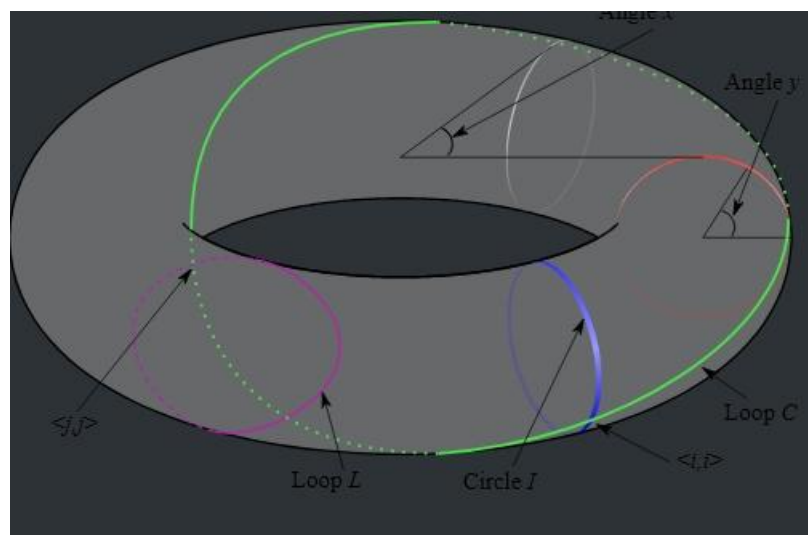
However, we have so far not used another continuity assumption which is also a reasonable assumption. So far, we have only made the following demand: the state the dial is in at stage S_2S_2 must be a continuous function of the state of the dial at stage S_3S_3 . But the state of the dial at stage S_2S_2 arrived at by taking the state of the dial at stage S_1S_1 , and rotating it over some angle. It is not merely the case that the effect of the interaction, namely the state of the dial at stage S_2S_2 ,

should be a continuous function of the cause, namely the state of the dial at stage S3S3. Additionally case the path taken to get there, the way the dial is rotated between stages S1S1 and S2S2 must be a continuous function of the state at stage S3S3. And, rather surprisingly, it turns out that this cannot be done. Let us illustrate the problem before going to a more general demonstration that there must be a fixed-point solution in the dial case.

Forget time travel for the moment. Suppose that you and I each have a watch with a single dial, neither of which is running. My watch is set at 12. You are going to announce what your watch is set at. My task is going to be to adjust my watch to yours no matter what announcement you make. And my actions should have a continuous (single-valued) dependence on the time that you announce. Surprisingly, this is not possible! For instance, suppose that if you announce “12”, then I achieve that setting on my watch by doing nothing. Now imagine slowly and continuously increasing the announced times, starting at 12. By continuity, I must achieve each of those settings by rotating my dial to the right. If at some point I switch and achieve the announced goal by a rotation of my dial to the left, I will have introduced a discontinuity in my actions, a discontinuity in the actions that I take as a function of the announced angle. So, I will be forced, by continuity, to achieve every announcement by rotating the dial to the right. But this rotation to the right will have to be abruptly discontinued as the announcements grow larger and I eventually approach 12 again, since I achieved 12 by not rotating the dial at all. So, there will be a discontinuity at 12 at the latest. In general, the continuity of my actions as a function of announced times cannot be maintained throughout if I am to be able to replicate all possible settings. Another way to see the problem is that one can similarly reason that, as one starts with 12, and imagines continuously making the announced times earlier, one will be forced, by continuity, to achieve the announced times by rotating the dial to the left. However, the conclusions drawn from the assumption of continuous increases and the assumption of continuous decreases are inconsistent. So, we have an inconsistency following from the assumption of continuity and the

assumption that I always manage to set my watch to your watch. So, a dial developing according to continuous dynamics from a given initial state, cannot be set up to react to a second dial, with which it interacts, in such a way that it is guaranteed to always end up set at the same angle as the second dial. Similarly, it cannot be set up so that it is guaranteed to always end up set at 90 degrees to the setting of the second dial. All of this has nothing to do with time travel. However, the impossibility of such setups is what prevents us from enacting the rotation by 90 degrees which would create a paradox in the time travel setting.

Let us now give the positive result that with such dials there will always be fixed-point solutions, as long as the dynamics are continuous. Let us call the state of the dial before it interacts with its older self the initial state of the dial. And let us call the state of the dial after it emerges from the time machine the final state of the dial. There is also an intermediate state of the dial after it interacts with its older self and before it is put into the time machine. We can represent the initial or intermediate states of the dial, before it goes into the time machine, as an angle xx in the horizontal plane, and the final state of the dial, after it comes out of the time machine, as an angle yy in the vertical plane. All



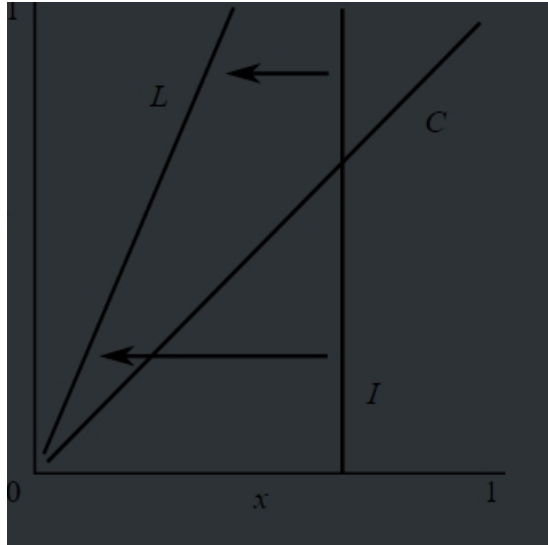
possible $\langle x,y \rangle$ pairs can thus be visualized as a torus with each xx value picking out a vertical circular cross-section and each yy picking out a point on that cross-section. See [Figure 1](#).

FIGURE 1 [An [extended description of Figure 1](#) is in the supplement.]

Suppose that the dial starts at angle ii which picks out vertical circle II on the torus. The initial angle II that the dial is at before it encounters its older self, and the set of all possible final angles that the dial can have when it emerges from the time machine is represented by the circle II on the torus (see [Figure 1](#)). Given any possible angle of the emerging dial, the dial initially at angle ii will develop to some other angle. One can picture this development by rotating each point on II in the horizontal direction by the relevant amount. Since the rotation has to depend continuously on the angle of the emerging dial, circle II during this development will deform into some loop LL on the torus.

Loop LL thus represents all possible intermediate angles xx that the dial is at when it is thrown into the time machine, given that it started at angle ii and then encountered a dial (its older self) which was at angle yy when it emerged from the time machine. We therefore have consistency if $x=yx=y$ for some xx and yy on loop LL . Now, let loop CC be the loop that consists of all the points on the torus for which $x=yx=y$. Ring II intersects CC at point $\langle i,i \rangle \langle i,i \rangle$. Any continuous deformation of II must still intersect CC somewhere. So LL must intersect CC somewhere, say at $\langle j,j \rangle \langle j,j \rangle$. But that means that no matter how the development of the dial starting at II depends on the angle of the emerging dial, there will be some angle for the emerging dial such that the dial will develop exactly into that angle (by the time it enters the time machine) under the influence of that emerging dial. This is so no matter what angle one starts with, and no matter how the development depends on the angle of the emerging dial. Thus, even for a circular state-space, there are no constraints needed other than continuity.

Unfortunately, there are state spaces that escape even this argument. Consider for instance a pointer that can be set to all values between 0 and 1, where 0 and 1 are not possible values. That is, suppose that we have a state space that is isomorphic to an open set of real numbers.



Now suppose that we have a machine that sets the pointer to half the value that the pointer is set at when it emerges from the time machine.

FIGURE 2 [An [extended description of Figure 2](#) is in the supplement.]

Suppose the pointer starts at value II . As before we can represent the combination of this initial position and all possible final positions by line II . Under the influence of the pointer coming out of the time machine, the pointer value will develop to a value that equals half the value of the final value that it encountered. We can represent this development as the continuous deformation of line II into line LL , which is indicated by the arrows in [Figure 2](#). This development is fully continuous. Points $\langle x, y \rangle$ on line II represent the initial position $x = Ix = I$ of the (young) pointer, and the position yy of the older pointer as it emerges from the time machine. Points $\langle x, y \rangle$ on line LL represent the position xx that the younger pointer should develop into, given that it encountered the older pointer emerging from the time machine set at position yy . Since the pointer is designed to develop to half the value of the pointer that it encounters, the line LL corresponds to $x = 1/2y$. We have consistency if there is some point such that it develops into that point if it encounters that point. Thus, we have consistency if there is some point $\langle x, y \rangle$ on line LL such that $x = y$. However, there is no such point: lines LL and CC do not

intersect. Thus, there is no consistent solution, even though the dynamics are fully continuous.

Of course, if 0 were a possible value, LL and CC would intersect at 0.

This is surprising and strange: adding one point to the set of possible values of a quantity here makes the difference between paradox and peace. One might be tempted to just add the extra point to the state space in order to avoid problems. After all, one might say, surely no measurements could ever tell us whether the set of possible values includes that exact point or not. Unfortunately, there can be good theoretical reasons for supposing that some quantities have an open state space: the set of all possible speeds of massive objects in special relativity surely is an open set, since it includes all speeds up to, but not including, the speed of light. Quantities that have possible values that are not bounded also lead to counterexamples to the presented fixed-point argument. And it is not obvious to us why one should exclude such possibilities. So, the argument that no constraints are needed is not fully general.

An interesting question of course is: exactly for which state-spaces must there be such fixed points? The arguments above depend on a well-known fixed-point theorem (due to Schauder) that guarantees the existence of a fixed point for compact, convex state spaces. We do not know what subsequent extensions of this result imply regarding fixed points for a wider variety of systems, or whether there are other general results along these lines. (See Kutach 2003 for more on this issue.)

A further interesting question is whether this line of argument is sufficient to resolve *Consistency* (see also Dowe 2007). When they apply, these results establish the existence of a solution, such as the shade of uniform gray in the first example. But physicists routinely demand more than merely the existence of a solution, namely that solutions to the equations are stable—such that “small” changes of the initial state lead to “small” changes in the resulting trajectory.

(Clarifying the two senses of “small” in this statement requires further work, specifying the relevant topology.) Stability in this sense underwrites the possibility of applying equations to real systems given

our inability to fix initial states with indefinite precision. (See Fletcher 2020 for further discussion.) The fixed-point theorems guarantee that for an initial state S_1 there is a solution, but this solution may not be “close” to the solution for a nearby initial state, S'_1 . We are not aware of any proof that the solutions guaranteed to exist by the fixed point theorems are also stable in this sense.

3. The General Possibility of Time Travel in General Relativity

Time travel has recently been discussed quite extensively in the context of general relativity. General relativity places few constraints on the global structure of space and time. This flexibility leads to a possibility first described in print by Hermann Weyl:

Every world point is the origin of the double cone of the active future and the passive past [i.e., the two lobes of the light cone]. Whereas in the special theory of relativity, these two portions are separated by an intervening region, it is certainly possible in the present case [i.e., general relativity] for the cone of the active future to overlap with that of the passive past; so that, in principle, it is possible to experience events now that will in part be an effect of my future resolves and actions. Moreover, it is not impossible for a world-line (in particular, that of my body), although it has a time-like direction at every point, to return to the neighborhood of a point which it has already passed through. (Weyl 1918/1920 [1952: 274])

A time-like curve is simply a space-time trajectory such that the speed of light is never equaled or exceeded along this trajectory. Time-like curves represent possible trajectories of ordinary objects. In general relativity a curve that is everywhere in time like locally can nonetheless loop back on itself, forming a CTC. Weyl makes the point vividly in terms of the light cones: along such a curve, the future lobe of the light cone (the “active future”) intersects the past lobe of the light cone (the “passive past”). Traveling along such a curve one would never exceed the speed of light, and yet after a certain amount of (proper) time, one would return to a point in space-time that one previously visited. Or, by staying close to such a CTC, one could come arbitrarily close to a point in

space-time that one previously visited. General Relativity, in a straightforward sense, allows for time travel: there appear to be many space-times compatible with the fundamental equations of general relativity in which there are CTC's. Space-time, for instance, could have a Minkowski metric everywhere, and yet have CTC's everywhere by having the temporal dimension (topologically) rolled up as a circle. Or, one can have wormhole connections between different parts of space-time which allow one to enter "mouth AA" of such a wormhole connection, travel through the wormhole, exit the wormhole at "mouth BB" and re-enter "mouth AA" again. CTCs can even arise when the spacetime is topologically R^4 , due to the "tilting" of light cones produced by rotating matter (as in Gödel 1949's spacetime). General relativity thus appears to provide ample opportunity for time travel. Note that just because there are CTC's in space-time, this does not mean that one can get from any point in space-time to any other point by following some future-directed time-like curve—there may be insurmountable practical obstacles. In Gödel's spacetime, it is the case that CTCs are passing through every point in the spacetime. Yet these CTCs are not geodesic, so traversing them requires acceleration. Calculations of the minimal fuel required to travel along the appropriate curve should discourage any would-be time travelers (Malamet 1984, 1985; Manchak 2011). But more generally CTCs may be confined to smaller regions; some parts of space-time can have CTC's while other parts do not. Let us call the part of space-time that has CTC's the "time travel region" of that space-time while calling the rest of that space-time the "normal region". More precisely, the "time travel region" consists of all the space-time points p such that there exists a (non-zero length) time-like curve that starts at p and returns to p . Now let us turn to examining spacetimes with CTC's a bit more closely for potential problems.

4. Two Toy Models

In order to get a feeling for the sorts of implications that closed time-like curves can have, it may be useful to consider two simple models. In space-times with closed time-like curves, the traditional initial value

problem cannot be framed in the usual way. For it presupposes the existence of Cauchy surfaces, and if there are CTCs then no Cauchy surfaces exist. (A Cauchy surface is a spacelike surface such that every inextendable time-like curve crosses it exactly once. One normally specifies initial conditions by giving the conditions on such a surface.) Nonetheless, if the topological complexities of the manifold are appropriately localized, we can come quite close. Let us call an edgeless spacelike surface SS a *quasi-Cauchy* surface if it divides the rest of the manifold into two parts such that

- a. every point in the manifold can be connected by a time-like curve to SS , and
- b. any time-like curve that connects a point in one region to a point in the other region intersects SS exactly once.

A quasi-Cauchy surface must entirely inhabit the normal region of space-time; if any point pp of SS is in the time travel region, then any time-like curve that intersects pp can be extended to a time-like curve that intersects SS near pp again. In extreme cases of time travel, a model may have no normal region at all (e.g., Minkowski space-time rolled up like a cylinder in a time-like direction), in which case our usual notions of temporal precedence will not apply. However, temporal anomalies like wormholes (and time machines) can be sufficiently localized to permit the existence of quasi-Cauchy surfaces.

Given a time-like orientation, a quasi-Cauchy surface unproblematically divides the manifold into its *past* (i.e., all points that can be reached by past-directed time-like curves from SS) and its *future* (ditto *mutatis mutandis*). If the whole past of SS is in the normal region of the manifold, then SS is a *partial Cauchy surface*: every inextendable time-like curve which exists to the past of SS intersects SS exactly once, but (if there is time travel in the future) not every inextendable time-like curve which exists to the future of SS intersects SS . Now we can ask a particularly clear question: consider a manifold that contains a time

travel region but also has a partial Cauchy surface SS , such that all of the temporal funny business is to the future of SS . If all you could see were SS and its past, you would not know that the space-time had any time travel at all. The question is: are there any constraints on the sort of data that can be put on SS and continued to a global solution of the dynamics that are different from the constraints (if any) on the data that can be put on a Cauchy surface in a simply connected manifold and continued to a global solution? If there is time travel to our future, might we be able to tell this now, because of some implied oddity in the arrangement of present things?

It is not at all surprising that there might be constraints on the data that can be put on a locally space-like surface that passes through the time travel region: after all, we never think we can freely specify what happens on a space-like surface and another such surface to its future, but in this case, the surface at issue lies to its future. But if there were particular constraints for data on a partial Cauchy surface then we would apparently need to have to rule out some sorts of otherwise acceptable states on SS if there is to be time travel to the future of SS . We then might be able to establish that there will be no time travel in the future by simple inspection of the present state of the universe. As we will see, there is reason to suspect that such constraints on the partial Cauchy surface are non-generic. But we are getting ahead of ourselves: first, let's consider the effect of time travel on very simple dynamics.

The simplest possible example is the Newtonian theory of perfectly elastic collisions among equally massive particles in one spatial dimension. The space-time is two-dimensional, so we can represent it initially as the Euclidean plane, and the dynamics is completely specified by two conditions. When particles are traveling freely, their world lines are straight lines in space-time, and when two particles collide, they exchange momenta, so the collision looks like an "XX" in space-time, with each particle changing its momentum at the impact. The dynamics are purely local, in that one can check that a set of world lines constitutes a model of the dynamics by checking that the dynamics

are obeyed in every arbitrarily small region. It is also trivial to generate solutions from arbitrary initial data if there are no CTCs: given the initial positions and momenta of a set of particles, one simply draws a straight line from each particle in the appropriate direction and continues it indefinitely. Once all the lines are drawn, the worldline of each particle can be traced from collision to collision. The boundary value problem for this dynamics is obviously well-posed: any set of data at an instant yields a unique global solution, constructed by the method sketched above.

What happens if we change the topology of the space-time by hand to produce CTCs? The simplest way to do this is depicted in [Figure 3](#): we cut and paste the space-time so it is no longer simply connected by identifying the line $L-L^-$ with the line $L+L^+$. Particles “going in” to $L+L^+$ from below “emerge” from $L-L^-$, and particles “going in” to $L-L^-$ from below “emerge” from $L+L^+$.

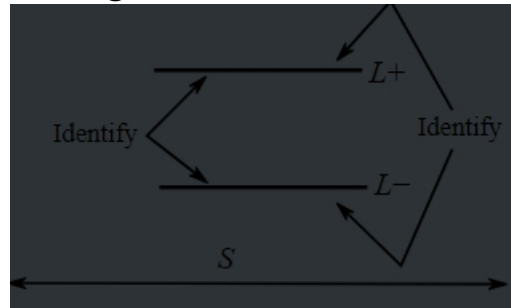


FIGURE 3: Inserting CTCs by Cut and Paste. [An [extended description of Figure 3](#) is in the supplement.]

How is the boundary-value problem changed by this alteration in the space-time? Before the cut and paste, we can put arbitrary data on the simultaneity slice SS and continue it to a unique solution. After the change in topology, SS is no longer a Cauchy surface, since a CTC will never intersect it, but it is a partial Cauchy surface. So, we can ask two questions. First, can arbitrary data on SS always be continued to a global solution? Second, is that solution unique? If the answer to the first question is nono, then we have a backward-temporal constraint: the existence of the region with CTCs places constraints on what can happen on SS even though that region lies completely to the future of SS . If the

answer to the second question is *no*, then we have an odd sort of indeterminism, analogous to the unwritten book: the complete physical state on SS does not determine the physical state in the future, even though the local dynamics is perfectly deterministic and even though there is no other past edge to the space-time region in SS 's future (i.e., there is nowhere *else* for boundary values to come from which could influence the state of the region).

In this case, the answer to the first question is *yes* and the second is *no*: there are no constraints on the data which can be put on SS , but those data are always consistent with an infinitude of different global solutions. The easy way to see that there always is a solution is to construct the minimal solution in the following way. Start drawing straight lines from SS as required by the initial data. If a line hits $L-L-$ from the bottom, just continue it coming out of the top of $L+L+$ in the appropriate place, and if a line hits $L+L+$ from the bottom, continue it emerging from $L-L-$ at the appropriate place. [Figure 4](#) represents the minimal solution for a single particle that enters the time-travel region from the left:

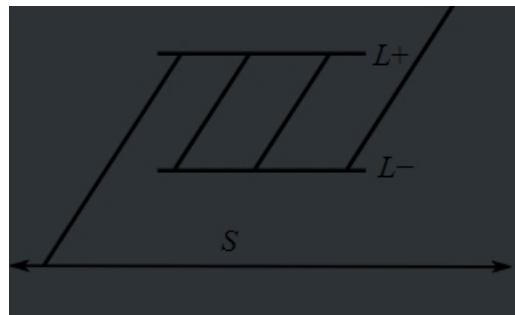


FIGURE 4: The Minimal Solution. [An [extended description of Figure 4](#) is in the supplement.]

The particle “travels back in time” three times. It is obvious that this minimal solution is a global solution since the particle always travels inertially.

However, the same initial state on SS is also consistent with other global solutions. The new requirement imposed by the topology is just that the

data going into $L+L+$ from the bottom match the data coming out of $L-L-$ from the top, and the data going into $L-L-$ from the bottom match the data coming out of $L+L+$ from the top. So we can add any number of vertical lines connecting $L-L-$ and $L+L+$ to a solution and still have a solution. For example, adding a few such lines to the minimal solution yields:

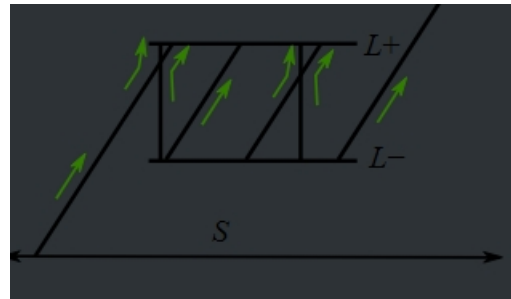


FIGURE 5: A Non-Minimal Solution. [An [extended description of Figure 5](#) is in the supplement.]

The particle now collides with itself twice: first before it reaches $L+L+$ for the first time, and again shortly before it exits the CTC region. From the particle's point of view, it is traveling to the right at a constant speed until it hits an older version of itself and comes to rest. It remains at rest until it is hit from the right by a younger version of itself, and then continues moving off, and the same process repeats later. It is clear that this is a global model of the dynamics, and that any number of distinct models could be generating by varying the number and placement of vertical lines.

Knowing the data on SS , then, gives us only incomplete information about how things will go for the particle. We know that the particle will enter the CTC region, and will reach $L+L+$, we know that it will be the only particle in the universe, we know exactly where and with what speed it will exit the CTC region. But we cannot determine how many collisions the particle will undergo (if any), nor how long (in proper time) it will stay in the CTC region. If the particle were a clock, we could not predict what time it would indicate when exiting the region. Furthermore, the dynamics gives us no handle on what to think of the

various possibilities: there are no probabilities assigned to the various distinct possible outcomes.

Changing the topology has changed the mathematics of the situation in two ways, which tend to pull in opposite directions. On the one hand, SS is no longer a Cauchy surface, so it is perhaps not surprising that data on SS do not suffice to fix a unique global solution. On the other hand, there is an added constraint: data “coming out” of $L-L-$ must exactly match data “going in” to $L+L+$, even though what comes out of $L-L-$ helps to determine what goes into $L+L+$. This added consistency constraint tends to cut down on solutions, although in this case, the additional constraint is more than outweighed by the freedom to consider various sorts of data on $L+/L-L+/L-$.

The fact that extra freedom outweighs the extra constraint also points to one unexpected way that the supposed paradoxes of time travel may be overcome. Let’s try to set up a paradoxical situation using the little closed-time loop above. If we send a single particle into the loop from the left and do nothing else, we know exactly where it will exit the right side of the time travel region. Now suppose we station someone at the other side of the region with the following charge: if the particle should come out on the right side, the person is to do something to *prevent* the particle from going in on the left in the first place. In fact, this is quite easy to do: if we send a particle in from the right, it seems that it can exit on the left and *deflect* the incoming left-hand particle.

Carrying on our reflection in this way, we further realize that if the particle comes out on the right, we might as well send *it* back in order to deflect itself from entering in the first place. So, all we need to do is the following: set up a perfectly reflecting particle mirror on the right-hand side of the time travel region, and launch the particle from the left so that—if *nothing interferes with it*—it will just barely hit $L+L+$. Our paradox is now apparently complete. If, on the one hand, nothing interferes with the particle it will enter the time-travel region on the left, exit on the right, be reflected from the mirror, re-enter from the right, and come out on the left to prevent itself from ever entering. So if it

enters, it gets deflected and never enters. On the other hand, if it never enters then nothing goes in on the left, so nothing comes out on the right, so nothing is reflected back, and there is nothing to deflect it from entering. So, if it doesn't enter, then there is nothing to deflect it and it enters. If it enters, then it is deflected and doesn't enter; if it doesn't enter then there is nothing to deflect it and it enters: paradox complete. But at least one solution to the supposed paradox is easy to construct: just follow the recipe for constructing the minimal solution, continuing the initial trajectory of the particle (reflecting it in the mirror in an obvious way), and then reading the number and trajectories of the particles from the resulting diagram. We get the result of [Figure 6](#):

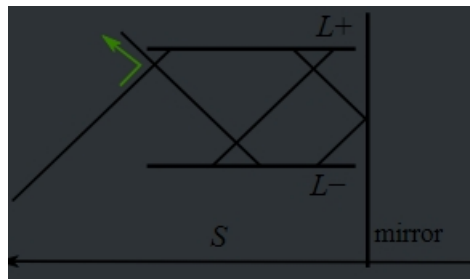


FIGURE 6: Resolving the “Paradox”. [An [extended description of Figure 6](#) is in the supplement.]

As we can see, the particle approaching from the left never reaches $L+L+$: it is deflected first by a particle that emerges from $L-L-$. But it is not deflected *by itself*, as the paradox suggests, it is deflected by another particle. Indeed, there are now *four* particles in the diagram: the original particle and three particles which are confined to closed time-like curves. It is not the leftmost particle, which is reflected by the mirror, nor even the particle that deflects the leftmost particle; it is another particle altogether.

The paradox gets its traction from an incorrect presupposition. If there is only one particle in the world at SS , then there is only one particle that could participate in an interaction in the time travel region; the single particle would have to interact with its earlier (or later) self. But there is no telling what might come out of $L-L-$: the only requirement is that whatever comes out must match what goes in at $L+L+$. So, if you go to

the trouble of constructing a working time machine, you should be prepared for a different kind of disappointment when you attempt to go back and kill yourself: you may be prevented from entering the machine in the first place by some completely unpredictable entity which emerges from it. And once again a peculiar sort of indeterminism appears: if there are many self-consistent things which could prevent you from entering, there is no telling which is even likely to materialize. This is just like the case of the unwritten book: the book is never written, so nothing determines what fills its pages.

So, when the freedom to put data on $L-L-$ outweighs the constraint that the same data go into $L+L+$, instead of paradox we get an embarrassment of riches: many solutions consistent with the data on SS , or many possible books. To see a case where the constraint “outweighs” the freedom, we need to construct a very particular, and frankly artificial, dynamics and topology. Consider the space of all linear dynamics for a scalar field on a lattice. (The lattice can be thought of as a simple discrete space-time.) We will depict the space-time lattice as a directed graph. There is to be a scalar field defined at every node of the graph, whose value at a given node depends linearly on the values of the field at nodes that have arrows that lead to it. Each edge of the graph can be assigned a weighting factor which determines how much the field at the input node contributes to the field at the output node. If we name the nodes by the letters a, b, c , etc., and the edges by their endpoints in an obvious way, then we can label the weighting factors by the edges they are associated with in an equally obvious way.

Suppose that the graph of the space-time lattice is *acyclic*, as in [Figure 7](#). (A graph is *Acyclic* if one cannot travel in the direction of the arrows and go in a loop.)

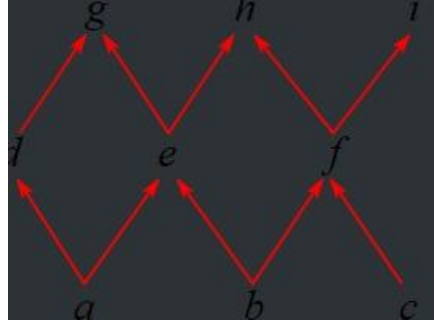


FIGURE 7: An Acyclic Lattice. [An [extended description of Figure 7](#) is in the supplement.]

It is easy to regard a set of nodes as the analog of a Cauchy surface, e.g., the set $\{a,b,c\}$, and it is obvious if arbitrary data are put on those nodes the data will generate a unique solution in the future.^[3] If the value of the field at node a is 3 and at node b is 7, then its value at node d will be $3W_{ad}+7W_{bd}$ and its value at node e will be $3W_{ae}+7W_{be}$. By varying the weighting factors we can adjust the dynamics, but in an acyclic graph the future evolution of the field will always be unique.

Let us now again artificially alter the topology of the lattice to admit CTCs, so that the graph now is cyclic. One of the simplest such graphs is depicted in [Figure 8](#): there are now paths which lead from z back to itself, e.g., z to y to z .

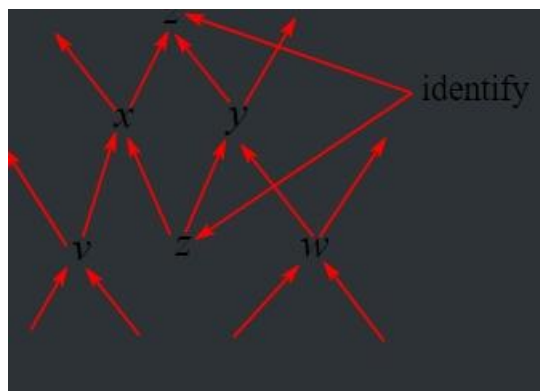


FIGURE 8: Time Travel on a Lattice. [An [extended description of Figure 8](#) is in the supplement.]

Can we now put arbitrary data on v and w , and continue that data to a global solution? Will the solution be unique?

In the generic case, there will be a solution, and the solution will be unique. The equations for the value of the field at x, y, z are:

$$x = vW_{vx} + zW_{zxy} = wW_{wy} + zW_{zyz} = xW_{xz} + yW_{yz}. x = vW_{vx} + zW_{zxy} = wW_{wy} + zW_{zyz} = xW_{xz} + yW_{yz}.$$

Solving these equations for z yields

$$z = (vW_{vx} + zW_{zx})W_{xz} + (wW_{wy} + zW_{zy})W_{yz}, z = (vW_{vx} + zW_{zx})W_{xz} + (wW_{wy} + zW_{zy})W_{yz},$$

or

$$z = (vW_{vx}W_{xz} + wW_{wy}W_{yz})(1 - W_{zx}W_{xz} - W_{zy}W_{yz}), z = (vW_{vx}W_{xz} + wW_{wy}W_{yz})(1 - W_{zx}W_{xz} - W_{zy}W_{yz}),$$

which gives a unique value for z in the generic case. But looking at the space of all possible dynamics for this lattice (i.e., the space of all possible weighting factors), we find a singularity in the case where $1 - W_{zx}W_{xz} - W_{zy}W_{yz} = 0$. If we choose weighting factors in just this way, then arbitrary data at v and w cannot be continued to a global solution. Indeed, if the scalar field is everywhere non-negative, then this particular choice of dynamics puts ironclad constraints on the value of the field at v and w : the field there must be zero (assuming $W_{vx}W_{vx}$ and $W_{wy}W_{wy}$ to be non-zero), and similarly all nodes in their past must have field value zero. If the field can take negative values, then the values at v and w must be so chosen that $vW_{vx}W_{xz} = -wW_{wy}W_{yz}$. In either case, the field values at v and w are severely constrained by the existence of the CTC region even though these nodes lie completely to the past of that region. It is this sort of constraint which we find to be unlike anything that appears in standard physics.

Our toy models suggest three things. The first is that it may be impossible to prove in complete generality that arbitrary data on a partial Cauchy surface can *always* be continued to a global solution: our artificial case provides an example where it cannot. The second is that

such odd constraints are not likely to be generic: we had to delicately fine-tune the dynamics to get a problem. The third is that the opposite problem, namely data on a partial Cauchy surface being consistent with *many* different global solutions, is likely to be generic: we did not have to do any fine-tuning to get this result.

This third point leads to a peculiar sort of indeterminism, illustrated by the case of the unwritten book: the entire state on SS does not determine what will happen in the future even though the local dynamics is deterministic and there are no other “edges” to space-time from which data could influence the result. What happens in the time travel region is constrained but not determined by what happens on SS , and the dynamics does not even supply any *probabilities* for the various possibilities. The example of the photographic negative discussed in section 2, then, seems likely to be unusual, for in that case there is a *unique* fixed point for the dynamics, and the set-up plus the dynamical laws *determine* the outcome. In the generic case one would rather expect *multiple* fixed points, with no room for anything to influence, even probabilistically, *which* would be realized. (See the supplement on [Remarks and Limitations on the Toy Models](#).)

It is ironic that time travel should lead generically not to contradictions or to constraints (in the normal region) but to *underdetermination* of what happens in the time travel region by what happens everywhere else (an underdetermination tied neither to a probabilistic dynamics nor to a free edge to space-time). The traditional objection to time travel is that it leads to contradictions: there is no consistent way to complete an arbitrarily constructed story about how the time traveler intends to act. Instead, though, it appears that the more significant problem is underdetermination: the story can be consistently completed in many different ways.

5. Slightly More Realistic Models of Time Travel

Echeverria, Klinkhammer, and Thorne (1991) considered the case of a 3-dimensional single hard spherical ball that can go through a single time-travel wormhole to collide with its younger self.

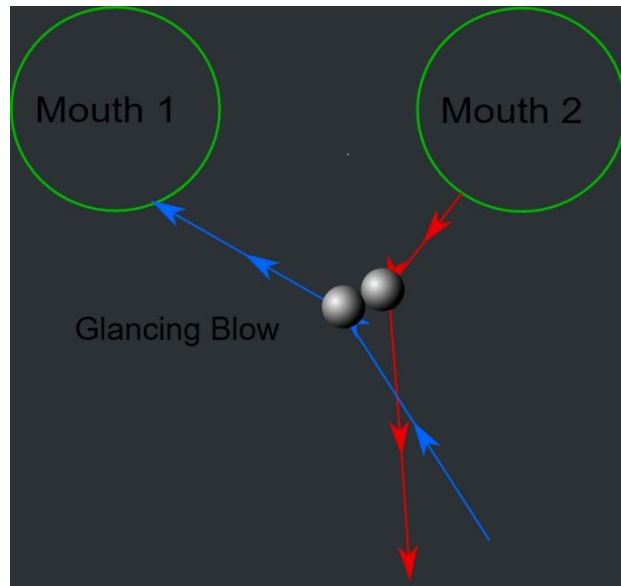


FIGURE 9 [An [extended description of Figure 9](#) is in the supplement.]

The threat of paradox in this case arises in the following form. Consider the initial trajectory of a ball as it approaches the time travel region. For some initial trajectories, the ball does not undergo a collision before reaching mouth 1, but upon exiting mouth 2 it will collide with its earlier self. This leads to a contradiction if the collision is strong enough to knock the ball off its trajectory and deflect it from entering mouth 1. Of course, the Wheeler-Feynman strategy is to look for a “glancing blow” solution: a collision that will produce exactly the (small) deviation in the trajectory of the earlier ball that produces exactly that collision. Are there always such solutions?

Echeverria, Klinkhammer & Thorne found a large class of initial trajectories that have consistent “glancing blow” continuations and found none that do not (but their search was not completely general). They did not produce rigorous proof that every initial trajectory has a consistent continuation but suggested that it is very plausible that every initial trajectory has a consistent continuation. That is to say, they have made it very plausible that, in the billiard ball wormhole case, the time travel structure of such a wormhole space-time does not result in constraints on states on spacelike surfaces in the non-time travel region.

As one might expect from our discussion in the previous section, they found the opposite problem from that of inconsistency: they found

underdetermination. For a large class of initial trajectories there are multiple different consistent “glancing blow” continuations of that trajectory (many of which involve multiple wormhole traversals). For example, if one initially has a ball that is traveling on a trajectory aimed straight between the two mouths, then one obvious solution is that the ball passes between the two mouths and never time travels. But another solution is that the younger ball gets knocked into mouth 1 exactly so as to come out of mouth 2 and produce that collision. Echeverria et al. do not note the possibility (which we pointed out in the previous section) of the existence of additional balls in the time travel region. We conjecture (but have no proof) that for every initial trajectory of AA there are some, and generically many, multiple-ball continuations.

Friedman, Morris, et al. (1990) examined the case of source-free non-self-interacting scalar fields traveling through such a time travel wormhole and found that no constraints on initial conditions in the non-time travel region are imposed by the existence of such time travel wormholes. In general, there appear to be no known counterexamples to the claim that in “somewhat realistic” time-travel space-times with a partial Cauchy surface there are no constraints imposed on the state on such a partial Cauchy surface by the existence of CTC’s. (See, e.g., Friedman & Morris 1991; Thorne 1994; Earman 1995; Earman, Smeenk, & Wüthrich 2009; and Dowe 2007.)

How about the issue of constraints in the time travel region TT? *Prima facie*, constraints in such a region would not appear to be surprising. But one might still expect that there should be no constraints on states on a spacelike surface, provided one keeps the surface “small enough”. In the physics literature, the following question has been asked: for any point pp in TT, and any space-like surface SS that includes pp is there a neighborhood EE of pp in SS such that any solution on EE can be extended to a solution on the whole space-time? Concerning this question, there are some simple models in which one has this kind of extendibility of local solutions to global ones and some simple models in which one does not have such extendibility, with no clear general

pattern. The technical mathematical problems are amplified by the more conceptual problem of what it might mean to say that one could create a situation that forces the creation of closed time-like curves. (See, e.g., Yurtsever 1990; Friedman, Morris, et al. 1990; Novikov 1992; Earman 1995; and Earman, Smeenk, & Wüthrich 2009). What are we to think of all of this?

6. The Possibility of Time Travel Redux

The toy models above all treat billiard balls, fields, and other objects propagating through a background spacetime with CTCs. Even if we can show that a consistent solution exists, there is a further question: what kind of matter and dynamics could generate CTCs to begin with? There are various solutions to Einstein's equations with CTCs, but how do these exotic spacetimes relate to the models used in describing the world? In other words, what positive reasons might we have to take CTCs seriously as a feature of the actual universe, rather than an exotic possibility of primarily mathematical interest?

We should distinguish two different kinds of “possibility” that we might have in mind in posing such questions (following Stein 1970). First, we can consider a solution as a candidate cosmological model, describing the (large-scale gravitational degrees of freedom of the) entire universe. The case for ruling out spacetimes with CTCs as potential cosmological models strikes us as, surprisingly, fairly weak. Physicists used to simply rule out solutions with CTCs as unreasonable by fiat, due to the threat of paradoxes, which we have dismantled above. But it is also challenging to make an observational case. Observations tell us very little about global features, such as the existence of CTCs, because signals can only reach an observer from a limited region of spacetime, called the past light cone. Our past light cone—and indeed the collection of all the past light cones for possible observers in a given spacetime—can be embedded in spacetimes with quite different global features (Malament 1977, Manchak 2009). This undercuts the possibility of using observations to constrain global topology, including (among other things) ruling out the existence of CTCs.

Yet the case in favor of taking cosmological models with CTCs seriously is also not particularly strong. Some solutions used to describe black holes, which are relevant in a variety of astrophysical contexts, include CTCs. However the question of whether the CTCs themselves play an essential representational role is subtle: the CTCs arise in the maximal extensions of these solutions and can plausibly be regarded as extraneous to successful applications. Furthermore, many of the known solutions with CTCs have symmetries, raising the possibility that CTCs are not a stable or robust feature. Slight departures from symmetry may lead to a solution without CTCs, suggesting that the CTCs may be an artifact of an idealized model.

The second sense of possibility regards whether “reasonable” initial conditions can be shown to lead to, or not to lead to, the formation of CTCs. As with the toy models above, suppose that we have a partial Cauchy surface SS , such that all the temporal funny business lies in the future. Rather than simply assuming that there is a region with CTCs in the future, we can ask instead whether it is possible to *create* CTCs by manipulating matter in the initial, well-behaved region, that is, whether it is possible to build a time machine. Several physicists have pursued “chronology protection theorems” aiming to show that the dynamics of general relativity (or some other aspects of physics) rule this out and to clarify why this is the case. The proof of such a theorem would justify neglecting solutions with CTCs as a source of insight into the nature of time in the actual world. But as of yet, several partial results do not fully settle the question. One further intriguing possibility is that even if general relativity by itself does protect chronology, it may not be possible to formulate a sensible theory describing matter and fields in solutions with CTCs. (See SEP entry on Time Machines; Smeenk and Wüthrich 2011 for more.)

There is a different question regarding the limitations of these toy models. The toy models and related examples show that there are consistent solutions for simple systems in the presence of CTCs. As usual we have made the analysis tractable by building toy models,

selecting only a few dynamic degrees of freedom, and tracking their evolution. But there is a large gap between the systems we have described and the time travel stories they evoke, with Kurt traveling along a CTC with murderous intentions. In particular, many features of the manifest image of time are tied to the thermodynamical properties of macroscopic systems. Rovelli (unpublished) considers an extremely simple system to illustrate the problem: can a clock move along a CTC? A clock consists of something in periodic motion, such as a pendulum bob, and something that counts the oscillations, such as an escapement mechanism. The escapement mechanism cannot work without friction; this requires dissipation and increasing entropy. For a clock that counts oscillations as it moves along a time-like trajectory, the entropy must be a monotonically increasing function. But that is incompatible with the clock returning to precisely the same state at some future time as it completes a loop. The point generalizes to imply that anything like a human, with memory and agency, cannot move along a CTC.

7. Even If There are Constraints, So What?

Since it is not obvious that one can rid oneself of all constraints in realistic models, let us examine the argument that time travel is implausible, and we should think it unlikely to exist in our world, in so far as it implies such constraints. The argument goes something like the following. To satisfy such constraints one needs some pre-established divine harmony between the global (time travel) structure of space-time and the distribution of particles and fields on space-like surfaces in it. But it is not plausible that the actual world, or any world even remotely like ours, is constructed with divine harmony as part of the plan. One might argue, that we have empirical evidence that conditions in any spatial region can vary quite arbitrarily. So, we have evidence that such constraints, whatever they are, do not exist in our world. So, we have evidence that there are no closed time-like lines in our world or one remotely like it. We will now examine this argument in more detail by presenting four possible responses, with counter-responses, to this argument.

Response 1. There is nothing implausible or new about such constraints. For instance, if the universe is spatially closed, there has to be enough matter to produce the needed curvature, and this puts constraints on the matter distribution on a space-like hypersurface. Thus, global space-time structure can quite unproblematically constrain matter distributions on space-like hypersurfaces in it. Moreover, we have no realistic idea what these constraints look like, so we hardly can be said to have evidence that they do not obtain.

Counterresponse 1. Of course, there are constraining relations between the global structure of space-time and the matter in it. The Einstein equations relate the curvature of the manifold to the matter distribution in it. But what is so strange and implausible about the constraints imposed by the existence of closed time-like curves is that these constraints in essence have nothing to do with the Einstein equations. When investigating such constraints one typically treats the particles and/or field in question as test particles and/or fields in a given space-time, i.e., they are assumed not to affect the metric of space-time in any way. In typical space-times without closed time-like curves, this means that one has, in essence, complete freedom of matter distribution on a space-like hypersurface. (See [response 2](#) for some more discussion of this issue). The constraints imposed by the possibility of time travel have quite different origins and are implausible. In the ordinary case, there is a causal interaction between matter and space-time that results in relations between the global structure of space-time and the matter distribution in it. In the time travel case, there is no such causal story to be told: there simply has to be some pre-established harmony between the global space-time structure and the matter distribution on some space-like surfaces. This is implausible.

Response 2. Constraints upon distribution are nothing new. For instance, Maxwell's equations constrain electric fields E on an initial surface to be related to the (simultaneous) charge density distribution q by the equation $q = \text{div}(E)$. (If we assume that the E field is generated solely by the charge distribution, this condition amounts to requiring that the E field at any point in space simply be the

one generated by the charge distribution according to Coulomb's inverse square law of electrostatics.) This is not implausible divine harmony. Such constraints can be held as a matter of physical law. Moreover, if we had inferred from the apparent free variation of conditions on spatial regions that there could be no such constraints we would have mistakenly inferred that $\rho = \text{div}(\mathbf{E})$ could not be a law of nature.

Counterresponse 2. The constraints imposed by the existence of closed time-like lines are of quite a different character from the constraint imposed by $\rho = \text{div}(\mathbf{E})$. The constraints imposed by $\rho = \text{div}(\mathbf{E})$ on the state on a space-like hypersurface are:

- i. local constraints (i.e., to check whether the constraint holds in a region you just need to see whether it holds at each point in the region),
- ii. quite independent of the global space-time structure,
- iii. quite independent of how the space-like surface in question is embedded in a given space-time, and
- iv. very simply and generally stateable.

On the other hand, the consistency constraints imposed by the existence of closed time-like curves (i) are not local, (ii) are dependent on the global structure of space-time, (iii) depend on the location of the space-like surface in question in a given space-time, and (iv) appear not to be simply stateable other than as the demand that the state on that space-like surface embedded in such and such a way in a given space-time, do not lead to inconsistency. On some views of laws (e.g., David Lewis' view) this plausibly implies that such constraints, even if they hold, could not possibly be laws. But even if one does not accept such a view of laws, one could claim that the bizarre features of such constraints imply that it is implausible that such constraints hold in our world or in any world remotely like ours.

Response 3. It would be strange if there were constraints in the non-time travel region. It is not strange if there are constraints in the time travel

region. They should be explained in terms of the strange, self-interactive, character of time travel regions. In this region, there are time-like trajectories from point to themselves. Thus, the state at such a point, in such a region, will, in a sense, interact with itself. It is a well-known fact that systems that interact with themselves will develop into an equilibrium state, if there is such an equilibrium state, or else will develop towards some singularity. Normally, of course, self-interaction isn't true instantaneous self-interaction but consists of a feedback mechanism that takes time. But in time travel regions something like true instantaneous self-interaction occurs. This explains why constraints on states occur in such time travel regions: the states "*ab initio*" have to be "equilibrium states". Indeed, in a way this also provides some picture of why indeterminism occurs in time travel regions: at the onset of self-interaction states can fork into different equi-possible equilibrium states.

Counterresponse 3. This is explained by the woolly analogy. It all goes to show that time travel leads to such bizarre consequences that it is unlikely that it occurs in a world remotely like ours.

Response 4. All of the previous discussion completely misses the point. So far, we have been taking the space-time structure as given and asked the question of whether a given time travel space-time structure imposes constraints on states on (parts of) space-like surfaces. However, space-time and matter interact. Suppose that one is in a space-time with closed time-like lines, such that certain counterfactual distributions of matter on some neighborhood of a point pp are ruled out if one holds that space-time structure fixed. One might then ask,

Why does the actual state near p satisfy these constraints? By what divine luck or plan is this local state compatible with the global space-time structure? What if conditions near p had been slightly different?

One might take it that the lack of normal answers to these questions indicates that it is very implausible that our world, or any remotely like it, is such a time travel universe. However, the proper response to this question is the following. There are no constraints in any significant

sense. If they hold, they hold as a matter of accidental fact, not of law. There is no more explanation of them possible than there is of any contingent fact. Had conditions in a neighborhood of p been otherwise, the global structure of space-time would have been different. So what? The only question relevant to the issue of constraints is whether an arbitrary state on an arbitrary spatial surface SS can always be embedded into a space-time such that that state on SS consistently extends to a solution on the entire space-time.

But we know the answer to that question. A well-known theorem in general relativity says the following: any initial data set on a three-dimensional manifold SS with positive definite metric has a unique embedding into a maximal space-time in which SS is a Cauchy surface (see, e.g., Geroch & Horowitz 1979: 284 for more detail), i.e., there is a unique largest space-time which has SS as a Cauchy surface and contains a consistent evolution of the initial value data on SS . Now since SS is a Cauchy surface this space-time does not have closed time-like curves. But it may have extensions (in which SS is not a Cauchy surface) that include closed time-like curves, indeed it may be that any maximal extension of it would include closed time-like curves. (This appears to be the case for extensions of states on certain surfaces of Taub-NUT space-times. See Earman, Smeenk, & Wüthrich 2009). But these extensions, of course, will be consistent. So properly speaking, there are no constraints on states on space-like surfaces. Nonetheless, the space-time in which these are embedded may or may not include closed time-like curves.

Counterresponse 4. This, in essence, is the stonewalling answer which we indicated in section 1. However, whether or not you call the constraints imposed by a given space-time on distributions of matter on certain space-like surfaces “genuine constraints”, whether or not they can be considered lawlike, and whether or not they need to be explained, the existence of such constraints can still be used to argue that time

travel worlds are so bizarre that it is implausible that our world or any world remotely like ours is a time travel world.

Suppose that one is in a time travel world. Suppose that given the global space-time structure of this world, there are constraints imposed upon, say, the state of motion of a ball on some space-like surface when it is treated as a test particle, i.e., when it is assumed that the ball does not affect the metric properties of the space-time it is in. (There are lots of other matter that, via the Einstein equation, corresponds exactly to the curvature that there is everywhere in this time travel worlds.) Now a real ball of course does have some effect on the metric of the space-time it is in. But let us consider a ball that is so small that its effect on the metric is negligible. Presumably, it will still be the case that certain states of this ball on that space-like surface are not compatible with the global time travel structure of this universe.

This means that the actual distribution of matter on such a space-like surface can be extended into space-time with closed time-like lines, but that certain counterfactual distributions of matter on this space-like surface cannot be extended into the same space-time. *But note that the changes made in the matter distribution (when going from the actual to the counterfactual distribution) do not in any non-negligible way affect the metric properties of space-time.* (Recall that the changes only affect test particles.) Thus, the reason why the global time travel properties of the counterfactual space-time have to be significantly different from the actual space-time is not that there are problems with metric singularities or alterations in the metric that force significant global changes when we go to the counterfactual matter distribution. The reason that the counterfactual space-time has to be different is that in the counterfactual world the ball's initial state of motion starting on the space-like surface, could not "meet up" in a consistent way with its earlier self (could not be consistently extended) if we were to let the global structure of the counterfactual space-time be the same as that of the actual space-time. Now, it is not bizarre or implausible that there is a counterfactual dependence of manifold structure, even of its topology, on matter distributions on spacelike surfaces. For instance, certain matter

distributions may lead to singularities, others may not. We may indeed in some sense have causal power over the topology of the space-time we live in. But this power normally comes via the Einstein equations. But it is bizarre to think that there could be a counterfactual dependence of global space-time structure on the arrangement of certain tiny bits of matter on some space-like surface, where changes in that arrangement by assumption do not affect the metric *anywhere in space-time in any significant way*. It is implausible that we live in such a world, or that a world even remotely like ours is like that.

Let us illustrate this argument differently by assuming that wormhole time travel imposes constraints upon the states of people before such time travel, where the people have so little mass/energy that they have a negligible effect, via the Einstein equation, on the local metric properties of space-time. Do you think it more plausible that we live in a world where wormhole time travel occurs but it only occurs when people's states are such that these local states happen to combine with time travel in such a way that nobody ever succeeds in killing their younger self, or do you think it more plausible that we are not in a wormhole time travel world?

8. Computational Models

An alternative approach to time travel (initiated by Deutsch 1991) abstracts away from the idealized toy models described above. This computational approach considers instead the evolution of bits (simple physical systems with two discrete states) through a network of interactions, which can be represented by a circuit diagram with gates corresponding to the interactions. Motivated by the possibility of CTCs, Deutsch proposed adding a new kind of channel that connects the *output* of a given gate back to its *input*—in essence, a backwards-time step. More concretely, given a gate that takes n bits as input, we can imagine taking some number $i < n$ of these bits through a channel that loops back and then does double duty as inputs. Consistency requires that the state of these i bits is the same for output and input. (We will consider an illustration of this kind of system in the next section.)

Working through examples of circuit diagrams with a CTC channel leads to similar treatments of *Consistency* and *Underdetermination* as the discussion above (see, e.g., Wallace 2012: § 10.6). But the approach offers two new insights (both originally due to Deutsch): the *Easy Knowledge* paradox, and a particularly clear extension to time travel in quantum mechanics.

A computer equipped with a CTC channel can exploit the need to find consistent evolution to solve remarkably hard problems. (This is quite different from the first idea that comes to mind to enhance computational power: namely, to just devote more time to a computation and then send the result back on the CTC to an earlier state.) The gate in a circuit incorporating a CTC implements a function from the input bits to the output bits, under the constraint that the output and input match the i bits going through the CTC channel. This requires, in effect, finding the fixed point of the relevant function. Given the generality of the model, there are few limits on the functions that could be implemented on the CTC circuit. Nature has to solve a hard computational problem just to ensure consistent evolution. This can then be extended to other complex computational problems—leading, more precisely, to solutions of **NP**-complete problems in polynomial time (see Aaronson 2013: Chapter 20 for an overview and further references). The limits imposed by computational complexity are an essential part of our epistemic situation, and computers with CTCs would radically change this.

9. Quantum Mechanics to the Rescue?

We now turn to the application of the computational approach to the quantum physics of time travel (see Deutsch 1991; Deutsch & Lockwood 1994). By contrast with the earlier discussions of constraints in classical systems, they claim to show that time travel never imposes any constraints on the pre-time travel state of quantum systems. The essence of this account is as follows.

A quantum system starts in state S_1 , interacts with its older self, after the interaction is in state S_2 , time travels while developing into state S_3 , then interacts with its younger self, and ends in state S_4 (see Figure 10).

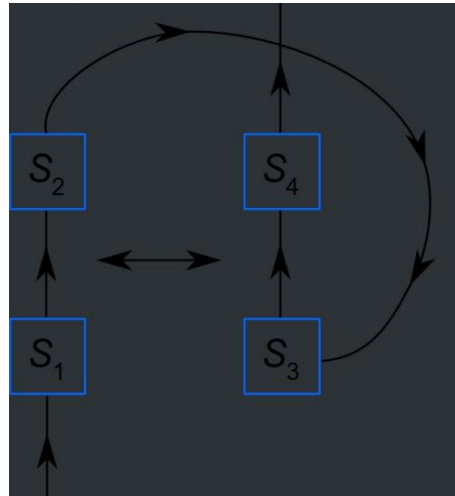


FIGURE 10 [An [extended description of Figure 10](#) is in the supplement.]

Deutsch assumes that the set of possible states of this system are the mixed states, i.e., represented by the density matrices over the Hilbert space of that system. Deutsch then shows that for any initial state S_1 , any unitary interaction between the older and younger self, and any unitary development during time travel, there is a consistent solution, i.e., there is at least one pair of states S_2 and S_3 such that when S_1 interacts with S_3 it will change to state S_2 and S_2 will then develop into S_3 . The states S_2 , S_3 and S_4 will typically not be pure states, i.e., will be non-trivial mixed states, even if S_1 is pure. To understand how this leads to interpretational problems let us give an example. Consider a system that has a two-dimensional Hilbert space with as a basis the states $|+\rangle|+\rangle$ and $|-\rangle|-\rangle$. Let us suppose that when state $|+\rangle|+\rangle$ of the young system encounters state $|+\rangle|+\rangle$ of the older system, they interact, and the young system develops into state $|-\rangle|-\rangle$ and the old system remains in state $|+\rangle|+\rangle$. In obvious notation:

$|+\rangle_1|+\rangle_3$ develops into $|-\rangle_2|+\rangle_4$. $|+\rangle_1|+\rangle_3$ develops into $|-\rangle_2|+\rangle_4$.
Similarly, suppose that:

$|+\rangle_1|-\rangle_3$ develops into $|+\rangle_2|-\rangle_4$, $|-\rangle_1|+\rangle_3$ develops into $|-\rangle_2|-\rangle_4$, and $|-\rangle_1|-\rangle_3$ develops into $|+\rangle_2|+\rangle_4$. $|+\rangle_1|-\rangle_3$ develops into $|+\rangle_2|-\rangle_4$, $|-\rangle_1|+\rangle_3$ develops into $|-\rangle_2|-\rangle_4$, and $|-\rangle_1|-\rangle_3$ develops into $|+\rangle_2|+\rangle_4$.

Let us furthermore assume that there is no development of the state of the system during time travel, i.e., that $|+\rangle_2|+\rangle_2$ develops into $|+\rangle_3|+\rangle_3$, and that $|-\rangle_2|-\rangle_2$ develops into $|-\rangle_3|-\rangle_3$.

Now, if the only possible states of the system were $|+\rangle|+\rangle$ and $|-\rangle|-\rangle$ (i.e., if there were no superpositions or mixtures of these states), then there is a constraint on initial states: initial state $|+\rangle_1|+\rangle_1$ is impossible. For if $|+\rangle_1|+\rangle_1$ interacts with $|+\rangle_3|+\rangle_3$ then it will develop into $|-\rangle_2|-\rangle_2$, which, during time travel, will develop into $|-\rangle_3|-\rangle_3$, which inconsistent with the assumed state $|+\rangle_3|+\rangle_3$.

Similarly, if $|+\rangle_1|+\rangle_1$ interacts with $|-\rangle_3|-\rangle_3$ it will develop into $|+\rangle_2|+\rangle_2$, which will then develop into $|+\rangle_3|+\rangle_3$ which is also inconsistent. Thus, the system cannot start in state $|+\rangle_1|+\rangle_1$.

But, says Deutsch, in quantum mechanics such a system can also be in any mixture of the states $|+\rangle|+\rangle$ and $|-\rangle|-\rangle$. Suppose that the older system, before the interaction, is in a state S_3 which is an equal mixture of 50% $|+\rangle_3|+\rangle_3$ and 50% $|-\rangle_3|-\rangle_3$. Then the younger system during the interaction will develop into a mixture of 50% $|+\rangle_2|+\rangle_2$ and 50% $|-\rangle_2|-\rangle_2$, which will then develop into a mixture of 50% $|+\rangle_3|+\rangle_3$ and 50% $|-\rangle_3|-\rangle_3$, which is consistent! More generally Deutsch uses a fixed-point theorem to show that no matter what the unitary development during interaction is, and no matter what the unitary development during time travel is, for any state S_1 there is always a state S_3 (which typically is not a pure state) which causes S_1 to develop into a state S_2 which develops into that state S_3 . Thus, quantum

mechanics comes to the rescue: it shows in all generality that no constraints on initial states are needed!

One might wonder why Deutsch appeals to mixed states: will superpositions of states $|+\rangle|+\rangle$ and $|-\rangle|-\rangle$ not suffice? Unfortunately, such an idea does not work. Suppose again that the initial state is $|+\rangle_1|+\rangle_1$. One might suggest that if state S_3 is

$$\frac{1}{\sqrt{2}}|+\rangle_3 + \frac{1}{\sqrt{2}}|-\rangle_3 \frac{1}{\sqrt{2}}|+\rangle_3 + \frac{1}{\sqrt{2}}|-\rangle_3$$

one will obtain a consistent development. One might think that when the initial state $|+\rangle_1|+\rangle_1$ encounters the superposition

$$\frac{1}{\sqrt{2}}|+\rangle_3 + \frac{1}{\sqrt{2}}|-\rangle_3, \frac{1}{\sqrt{2}}|+\rangle_3 + \frac{1}{\sqrt{2}}|-\rangle_3,$$

it will develop into a superposition

$$\frac{1}{\sqrt{2}}|+\rangle_2 + \frac{1}{\sqrt{2}}|-\rangle_2, \frac{1}{\sqrt{2}}|+\rangle_2 + \frac{1}{\sqrt{2}}|-\rangle_2,$$

and that this in turn will develop into

$$\frac{1}{\sqrt{2}}|+\rangle_3 + \frac{1}{\sqrt{2}}|-\rangle_3, \frac{1}{\sqrt{2}}|+\rangle_3 + \frac{1}{\sqrt{2}}|-\rangle_3,$$

as desired. However, this is not correct. For initial state $|+\rangle_1|+\rangle_1$ when it encounters

$$\frac{1}{\sqrt{2}}|+\rangle_3 + \frac{1}{\sqrt{2}}|-\rangle_3, \frac{1}{\sqrt{2}}|+\rangle_3 + \frac{1}{\sqrt{2}}|-\rangle_3,$$

will develop into an entangled state

$$\frac{1}{\sqrt{2}}|-\rangle_2|+\rangle_4 + \frac{1}{\sqrt{2}}|+\rangle_2|-\rangle_4, \frac{1}{\sqrt{2}}|-\rangle_2|+\rangle_4 + \frac{1}{\sqrt{2}}|+\rangle_2|-\rangle_4.$$

In so far as one can speak of the state of the young system after this interaction, it is in the mixture of 50% $|+\rangle_2|+\rangle_2$ and 50% $|-\rangle_2|-\rangle_2$, not in the superposition

$$\frac{1}{\sqrt{2}}|+\rangle_2 + \frac{1}{\sqrt{2}}|-\rangle_2 \cdot \frac{1}{\sqrt{2}}|+\rangle_2 + \frac{1}{\sqrt{2}}|-\rangle_2.$$

So, Deutsch does need his recourse to mixed states.

This clarification of why Deutsch needs his mixtures does however indicate a serious worry about the simplifications that are part of Deutsch's account. After the interaction, the old and young systems will (typically) be in an entangled state. Although for purposes of a measurement on one of the two systems one can say that this system is in a mixed state, one cannot represent the full state of the two systems by specifying the mixed state of each separate part, as there are correlations between observables of the two systems that are not represented by these two mixed states but are represented in the joint entangled state. But if there really is an entangled state of the old and young systems directly after the interaction, how is one to represent the subsequent development of this entangled state? Will the state of the younger system remain entangled with the state of the older system as the younger system time travels and the older system moves on into the future? On what space-like surfaces are we to imagine this total entangled state to be? At this point it becomes clear that there is no obvious and simple way to extend elementary non-relativistic quantum mechanics to space-times with closed time-like curves: we apparently need to characterize not just the entanglement between two systems, but entanglement relative to specific spacetime descriptions.

How does Deutsch avoid these complications? Deutsch assumes a mixed state S_3 of the older system prior to the interaction with the younger system. He lets it interact with an arbitrary pure state S_1 younger system. After this interaction, there is an entangled state S' of the two systems. Deutsch computes the mixed state S_2 of the younger system which is implied by this entangled state $S'S'$. His demand for consistency

then is just that this mixed state S_2 develops into the mixed state S_3 . Now it is not at all clear that this is a legitimate way to simplify the problem of time travel in quantum mechanics. But even if we grant him this simplification there is a problem: how are we to understand these mixtures?

If we take an ignorance interpretation of mixtures we run into trouble. For suppose that we assume that in each individual case each older system is either in state $|+\rangle_3|+\rangle_3$ or in state $|-\rangle_3|-\rangle_3$ prior to the interaction. Then we regain our paradox. Deutsch instead recommends the following, many worlds, pictures of mixtures. Suppose we start with state $|+\rangle_1|+\rangle_1$ in all worlds. In some of the many worlds the older system will be in the $|+\rangle_3|+\rangle_3$ state, let us call them *A*-worlds, and in some worlds, *B*-worlds, it will be in the $|-\rangle_3|-\rangle_3$ state. Thus in *A*-worlds after interaction we will have state $|-\rangle_2|-\rangle_2$, and in *B*-worlds we will have state $|+\rangle_2|+\rangle_2$. During time travel the $|-\rangle_2|-\rangle_2$ state will remain the same, i.e., turn into state $|-\rangle_3|-\rangle_3$, but the systems in question will travel from *A*-worlds to *B*-worlds. Similarly, the $|+\rangle_2|+\rangle_2$ states will travel from the *B*-worlds to the *A*-worlds, thus preserving consistency. Now whatever one thinks of the merits of many worlds interpretations, and of this understanding of it applied to mixtures, in the end one does not obtain genuine time travel in Deutsch's account. The systems in question travel from one time in one world to another time in another world, but no system travels to an earlier time in the same world. (This is so at least in the normal sense of the word "world", the sense that one means when, for instance, one says "there was, and will be, only one Elvis Presley in this world.") Thus, even if it were a reasonable view, it is not quite as interesting as it may have initially seemed. (See Wallace 2012 for a more sympathetic treatment, that explores several further implications of accepting time travel in conjunction with the many worlds interpretation.)

We close by acknowledging that Deutsch's starting point—the claim that this computational model captures the essential features of quantum systems in a spacetime with CTCs—has been the subject of some

debate. Several physicists have pursued a quite different treatment of the evolution of quantum systems through CTC's, based on considering the "post-selected" state (see Lloyd et al. 2011). Their motivations for implementing the consistency condition in terms of the post-selected state reflects a different stance towards quantum foundations. A different line of argument aims to determine whether Deutsch's treatment holds as an appropriate limiting case of a more rigorous treatment, such as quantum field theory in curved spacetimes. For example, Verch (2020) establishes several results challenging the assumption that Deutsch's treatment is tied to the presence of CTC's, or that it is compatible with the entanglement structure of quantum fields.

10. Conclusions

What remains of the grandfather paradox in general relativistic time travel worlds is the fact that in some cases the states on edgeless spacelike surfaces are "overconstrained", so that one has less than the usual freedom in specifying conditions on such a surface, given the time-travel structure, and in some cases such states are "underconstrained", so that states on edgeless space-like surfaces do not determine what happens elsewhere in the way that they usually do, given the time travel structure. There can also be mixtures of those two types of cases. The extent to which states are overconstrained and/or underconstrained in realistic models is as yet unclear, though it would be very surprising if neither obtained. The extant literature has primarily focused on the problem of overconstraint, since that, often, either is regarded as a metaphysical obstacle to the possibility time travel, or as an epistemological obstacle to the plausibility of time travel in our world. While it is true that our world would be quite different from the way we normally think it is if states were overconstrained, underconstraint seems at least as bizarre as overconstraint. Nonetheless, neither directly rules out the possibility of time travel.

If time travel entailed contradictions then the issue would be settled. And indeed, most of the stories employing time travel in popular culture are logically incoherent: one cannot "change" the past to be different

from what it was, since the past (like the present and the future) only occurs once. But if the only requirement demanded is logical coherence, then it seems all too easy. A clever author can devise a coherent time-travel scenario in which everything happens just once and in a consistent way. This is just too cheap: logical coherence is a very weak condition, and many things we take to be metaphysically impossible are logically coherent. For example, it involves no logical contradiction to suppose that water is not molecular, but if both chemistry and Kripke are right it is a metaphysical impossibility. We have been interested not in logical possibility but in physical possibility. But even so, our conditions have been relatively weak: we have asked only whether time travel is consistent with the universal validity of certain fundamental physical laws and with the notion that the physical state on a surface prior to the time travel region be unconstrained. It is perfectly possible that the physical laws obey this condition, but still time travel is not metaphysically possible because of the nature of time itself. Consider an analogy. Aristotle believed that water is homoiomerous and infinitely divisible: any bit of water could be subdivided, in principle, into smaller bits of water. Aristotle's view contains no logical contradiction. It was certainly consistent with Aristotle's conception of water that it be homoiomerous, so this was, for him, a conceptual possibility. But if chemistry is right, Aristotle was wrong both about what water is like and what is possible for it. It can't be infinitely divided, even though no logical or conceptual analysis would reveal that.

Similarly, even if all of our consistency conditions can be met, it does not follow that time travel is physically possible, only that some specific physical considerations cannot rule it out. The only serious proof of the possibility of time travel would be a demonstration of its actuality. For if we agree that there is no actual time travel in our universe, the supposition that there might have been involves postulating a substantial difference from actuality, a difference unlike in kind from anything we could know if firsthand. It is unclear to us exactly what the content of possible would be if one were to either maintain or deny the possibility of time travel in these circumstances, unless one merely meant that the

possibility is not ruled out by some delineated set of constraints. As the example of Aristotle's theory of water shows, conceptual and logical "possibility" do not entail possibility in a full-blooded sense. What exactly such a full-blooded sense would be in case of time travel, and whether one could have reason to believe it to obtain, remain to us obscure.

Is time travel even possible? An astrophysicist explains the science behind the science fiction

Published: Nov 13, 2023

Have you ever dreamed of traveling through time, like characters do in science fiction movies? For centuries, the concept of time travel has captivated people's imaginations. Time travel is the concept of moving between different points in time, just like you move between different places. In movies, you might have seen characters using special machines, magical devices or even hopping into a futuristic car to travel backward or forward in time.

But is this just a fun idea for movies, or could it really happen?

The question of whether time is reversible remains one of the biggest unresolved questions in science. If the universe follows the **laws of thermodynamics**, it may not be possible. The second law of thermodynamics states that things in the universe can either remain the same or become more disordered over time.

It's a bit like saying you can't unscramble eggs once they've been cooked. According to this law, the universe can never go back exactly to how it was before. Time can only go forward, like a one-way street.

Time is relative

However, physicist Albert Einstein's **theory of special relativity** suggests that time passes at different rates for different people. Someone speeding along on a spaceship moving close to the **speed of light** – 671 million miles per hour! – will experience time slower than a person on Earth.

People have yet to build spaceships that can move at speeds anywhere near as fast as light, but astronauts who visit the International Space Station orbit around the Earth at speeds close to 17,500 mph. Astronaut Scott Kelly has spent 520 days at the International Space Station, and as a result has aged a little more slowly than his twin brother – and fellow astronaut – Mark Kelly. Scott used to be 6 minutes younger than his twin brother. Now, because Scott was traveling so much faster than Mark and for so many days, he is **6 minutes and 5 milliseconds younger**.

Time isn't the same everywhere.

Some scientists are exploring other ideas that could theoretically allow time travel. One concept involves **wormholes**, or hypothetical tunnels in space that could create shortcuts for journeys across the universe. If someone could build a wormhole and then figure out a way to move one end at close to the speed of light – like the hypothetical spaceship mentioned above – the moving end would age more slowly than the stationary end. Someone who entered the moving end and exited the wormhole through the stationary end would come out in their past.

However, wormholes remain theoretical: Scientists have yet to spot one. It also looks like it would be **incredibly challenging** to send humans through a wormhole space tunnel.

Paradoxes and failed dinner parties

There are also paradoxes associated with time travel. The famous "**grandfather paradox**" is a hypothetical problem that could arise if someone traveled back in time and accidentally prevented their grandparents from meeting. This would create a paradox where you were never born, which raises the question: How

could you have traveled back in time in the first place? It's a mind-boggling puzzle that adds to the mystery of time travel.

Famously, physicist Stephen Hawking tested the possibility of time travel by **throwing a dinner party** where invitations noting the date, time and coordinates were not sent out until after it had happened. His hope was that his invitation would be read by someone living in the future, who had capabilities to travel back in time. But no one showed up.

As he **pointed out**: "The best evidence we have that time travel is not possible, and never will be, is that we have not been invaded by hordes of tourists from the future."

Telescopes are time machines

Interestingly, astrophysicists armed with powerful telescopes possess a unique form of time travel. As they peer into the vast expanse of the cosmos, they gaze into the past universe. Light from all galaxies and stars takes time to travel, and these beams of light carry information from the distant past. When astrophysicists observe a star or a galaxy through a telescope, they are not seeing it as it is in the present, but as it existed when the light began its journey to Earth millions to billions of years ago.

<https://www.youtube.com/embed/QeRtcJi3V38?wmode=transparent&start=0>
Telescopes are a kind of time machine – they let you peer into the past.

NASA's newest space telescope, the **James Webb Space Telescope**, is peering at galaxies that were formed at the very beginning of the Big Bang, about 13.7 billion years ago.

While we aren't likely to have time machines like the ones in movies anytime soon, scientists are actively researching and exploring new ideas. But for now, we'll have to enjoy the idea of time travel in our favorite books, movies and dreams.

Is time travel really possible? Here's what physics says

12 November 2023

The ability to jump forward and backwards in time has long fascinated science fiction writers and physicists alike. So is it really possible to travel into the past and the future?

Doctor Who is arguably one of the most famous stories about time travel. Alongside The Time Machine and Back to the Future, it has explored the temptations and paradoxes of [visiting the past and voyaging into the future](#).

In the TV show, the Doctor travels through time in the Tardis: an advanced craft that can go anywhere in time and space. Famously, the Tardis defies our understanding of physical space: [it's bigger on the inside than it appears on the outside](#).

Time: The Ultimate Guide

To mark the [60th anniversary of Doctor Who](#), we're exploring the big questions about time, including the science of time travel, how clocks have shaped humanity, and even the mind-bending temporal consequences of flying into a black hole. *Read and watch more from [Time: The Ultimate Guide](#).*

While time travel is fundamental to Doctor Who, the show never tries to ground the Tardis' abilities in anything resembling real-world physics. It would be odd to complain about this: Doctor Who has a fairy-tale quality and doesn't aspire to be realistic science fiction.

But what about in the real world? Could we ever build a time machine and travel into the distant past, or forward to see our great-great-great-grandchildren? Answering this question requires understanding how time actually works – something physicists are far from certain about. So far, what we can say with confidence is that travelling into the future is achievable, but travelling into the past is either wildly difficult or absolutely impossible.

Let's start with Albert Einstein's theories of relativity, which set out a description of space, time, mass and gravity. A key outcome of relativity is that the [flow of time isn't constant](#). Time can speed up or slow down, depending on the circumstances.

"This is where time travel can come in and it is scientifically accurate and there are real-world repercussions from that," says Emma Osborne, an astrophysicist at the University of York, in the UK.

For example, time passes more slowly if you travel at speed, though you need to start approaching the speed of light for the effect to be significant. This gives rise to the twin paradox, in which one of two identical twins becomes an astronaut and whizzes around in space at close to the speed of light, while the other stays on Earth. The astronaut will age more slowly than their Earthbound twin. "If you travel and come back, you are really younger than the twin brother," says Vlatko Vedral, a quantum physicist at the University of Oxford, in the UK. Twins Scott and Mark Kelly did this for real when [Scott spent months in space](#), albeit not at speeds close to that of light.

Similarly, time passes more slowly for you if you are in an intense gravitational field, such as a black hole. "Your head is ageing quicker than your feet, because Earth's gravity is stronger at your feet," says Osborne.

Doctor Who used this as the setup for season 10 finale World Enough and Time, in which the Twelfth Doctor and his friends are trapped on a spaceship close to a black hole. At the front of the craft, closer to the black hole, time passes more slowly than at the rear. This means the small group of Cybermen at the rear of the craft are able to develop into a huge army in, from the Doctor's point of view, a matter of minutes. This effect of gravity on time also features in the plot of the film Interstellar.

In our everyday lives, these relativistic effects are too tiny to be noticed. But they do affect [the satellites that we use for global positioning system \(GPS\)](#). "The clocks above tick faster than the clocks on Earth", and must be constantly readjusted, says Osborne. "If we didn't, Google Maps would be [wrong about 10km \(six miles\) a day](#)."

Relativity means it is possible to travel into the future. We don't even need a time machine, exactly. We need to either travel at speeds close to the speed of light, or spend time in an intense gravitational field. In relativity, these two acts are essentially equivalent. Either way, you will experience a relatively short amount of subjective time, while decades or centuries pass in the rest of the Universe. If you want to see what happens hundreds of years from now, this is how to do it.

In contrast, going backwards in time looks far, far harder.

"It may or may not be possible," says Barak Shoshany, a theoretical physicist at Brock University in St Catharines, Canada. "What we have right now is just insufficient knowledge, possibly insufficient theories."

In theory, it is possible for space-time to be folded like a piece of paper, allowing a tunnel to be punched through

Relativity offers some options for backwards time travel, but this time they are much more theoretical. "People tie themselves up in knots trying to find ways to rearrange space-time in order to make time travel to the past possible," says Katie Mack, a theoretical cosmologist at the Perimeter Institute for Theoretical Physics in Waterloo, Canada.

One way is to create a closed time-like curve: a path through space and time that loops back on itself. A person who followed the path would eventually find themselves at the same time and place where they started. A mathematical description of such a path was published by logician Kurt Gödel in [a 1949 study](#), and many others have followed.

However, this doesn't look like a promising approach for several reasons.

"We don't know whether this exists anywhere in the Universe," says Vedral. "This is really purely theoretical, there's no evidence."

It's also not at all obvious how we could make such a thing. "Even if we had much greater technological powers than we currently do, it seems unlikely that we

would be able to create closed time-like curves on purpose," says Emily Adlam, a philosopher at Chapman University in California, US.

Even if we could, says Vedral, we wouldn't want to. "You would literally be repeating exactly the same thing over and over again," he says.

Doctor Who used a similar setup in the classic episode Heaven Sent, in which the Doctor lives the same few hours over and over again for billions of years.

However, this didn't involve a closed time-like curve, but rather repeated use of a teleporter.

In a similar vein, in [a 1991 study](#) physicist Richard Gott set out a mathematical description of a wild scenario in which two "[cosmic strings](#)" moved past each other in opposite directions. According to his calculations, this would create closed time-like curves looping around the strings.

That sounds handy, but where might we find a pair of cosmic strings? They are hypothetical phenomena that may have formed in the very early Universe, according to some theories. None have ever been detected. "We don't have any reason to believe cosmic strings exist," says Mack. Even if they do exist, it would be an incredible stroke of luck to find two moving neatly in parallel. "We don't have any reason to believe that would happen."

Why is the Tardis a police box?

The Tardis allows Doctor Who to travel through time. It also has an iconic appearance. Owing to a faulty camouflage system, it has got stuck in the form of an old British police box. Within the show, the camouflage function is called the chameleon circuit, which is a distressing mistake because chameleons mostly change color to signal to each other, not to disguise themselves.

There is another phenomenon that is seemingly allowed by relativity: [wormholes](#). In theory, it is possible for space-time to be folded like a piece of paper, allowing [a tunnel to be punched through](#) to create a shortcut between two widely-separated points. "Wormholes are theoretically possible in general relativity," says Vedral.

However, again, the problems quickly mount up. First, we have no evidence that wormholes actually exist. "It's been shown mathematically that they can exist, but whether they exist physically is something else," says Osborne.

What's more, if wormholes do exist, they will be incredibly short-lived. "Often wormholes are described as two black holes that have joined to each other," says Osborne. This means a wormhole would have an incredibly intense gravitational field. "It would collapse under its own gravity."

Real wormholes would also be [microscopically tiny](#). You couldn't fit a person, or even a bacterium, through one.

In theory, both these problems can be solved – but this requires an enormous amount of something called "negative energy". This is something that may occur on the absolute tiniest scale, within spaces smaller than atoms. An energy field must have an overall positive energy, but there can be tiny pockets of negative energy within it, says Osborne. "What you'd want is these tiny pockets of locally negative energy expanded," she says. "I don't think that's possible in any way."

Vedral sums it up: "It doesn't sound like a very realistic proposal."

So much for time travel based on relativity. What about the other great theory of the Universe: quantum mechanics?

Whereas relativity describes the behaviour of large objects like humans and galaxies, quantum mechanics describes the very small – in particular, particles smaller than atoms, such as electrons and photons. On these subatomic scales, physics operates in ways that confound our intuitions.

One of the peculiar observations that has emerged from the study of the quantum realm is non-locality. A change in a particle's state in one location can instantaneously influence another "entangled" particle somewhere else – something Einstein referred to as "spooky action at a distance". This has been ["shown experimentally"](#) many times in Nobel Prize winning research, says Adlam.

"A lot of physicists are very unhappy with the possibility of non-locality," says Adlam. That's because, for the effect to be instantaneous, the information must

be conveyed from place to place at faster than the speed of light. This is supposed to be impossible.

In response, some physicists have proposed [alternative ways](#) to [interpret the experiments](#). These interpretations get rid of the non-locality – but in doing so they mess with our understanding of time.

"Instead of having an instantaneous non-local effect, you would just send your effect into the future, and then at some point it would turn around and go back into the past," says Adlam. "It would look instantaneous." But in reality, the effect would have gone on a journey into the future and back again.

This interpretation appears to introduce "retrocausality": that is, events in the future having an effect on the past. This goes against our intuition: we imagine events occurring in a straight line, from [the past to the present to the future](#). In these peculiar quantum setups, information may be travelling into the future and then back into the past.

The first thing to note is that this interpretation of the experiments is [far from universally accepted](#). Plenty of quantum physicists argue that introducing retrocausality is just as unsettling as introducing non-locality, or even worse.

For one thing, our observations of non-locality have all involved tiny numbers of particles. Scaling up to a human, or even something smaller like a piece of paper, would be an enormous challenge.

It isn't even possible to send a message into the past, says Adlam. "The retrocausality is very specifically hidden by the way it's implemented."

This is best understood by thinking through an experiment. Suppose Adam conducts a measurement in the lab. However, the result he gets is dependent on a measurement that Beth does later. In other words, Beth's experiment in the future controls the outcome of Adam's experiment in the past. However, this only works if Beth's experiment destroys all the records of what Adam did and saw.

"You sort of in some sense would be sending a signal to the past, but only by destroying all the records of everything that happened," says Adlam. "You

wouldn't be able to make practical use of that, because you necessarily had to destroy the records of succeeding and sending that signal."

So there we have it. On our current understanding of the Universe, we could potentially travel into the future, but travelling into the past may well be a total no-no.

The only remaining loophole is that the theories this is based on are incomplete. Relativity and quantum mechanics work very well for certain aspects of the Universe, but they also aren't compatible. This suggests we need a deeper theory that unifies the two, but despite decades of effort we don't have one. "Until we have that theory, we cannot be sure," says Shoshany.

Of course, there is another way of looking at it: in the time it has taken you to read this article, you've already travelled seven minutes or so into the future. You're welcome.

Could time travel actually be possible? One researcher thinks so

Time travel is one of the most captivating tropes in science fiction, inspiring countless stories of adventures through the ages. After all, what's more tantalizing than the possibility of rewriting history? Yet, this concept has always run into fundamental contradictions — like the infamous “[grandfather paradox](#),” where changing the past seems to erase the time traveler's very existence.

Now, [a new study](#) by Lorenzo Gavassino, a Vanderbilt University physicist, explores how quantum mechanics and thermodynamics might resolve such paradoxes, offering a theoretical glimpse into how time travel could actually work without breaking reality.

Twisting Space-Time into Loops

It's hard to say who ever thought about time travel, but the physical concept of time travel typically traces back to Albert Einstein's [theory of general relativity](#). This theory shows that space-time can curve in unusual ways. Under certain extreme conditions, it might bend so dramatically that it loops back on itself, creating what physicists call a “[closed timelike curve](#).” Imagine following a path through space-time that eventually leads you to the exact point in history — including your own personal history — from which you set out.

Though these loops are mathematically allowed by Einstein's equations, they spark a series of “what if?” questions. In addition to paradoxes like the grandfather scenario, skeptics have long pointed out another issue: the [second law of thermodynamics](#), which states that the overall disorder (or entropy) in a system cannot decrease with time. If you could travel in a closed loop, how would the usual march of entropy proceed, and how could any contradiction be prevented?

For physicists, this is the stuff of nightmares. But Gavassino took them on.

The new study tackles these questions by focusing on the [thermodynamic arrow of time](#) — the familiar one-way direction in which events unfold, food spoils, and we all age. Entropy is the key to this arrow. Under normal, everyday conditions, entropy only goes up.

But, the paper suggests that within a closed timelike curve, [quantum fluctuations](#) could disrupt this pattern. These fluctuations might act like tiny corrections to the ordinary laws of thermodynamics, allowing entropy to decrease in a localized way when traveling around the loop.

By partially reversing the arrow of time, processes previously believed to be impossible — such as “undoing” an irreversible event or preventing it from ever fully taking place — might become feasible along the curve. This mechanism would keep the laws of physics intact overall, even if local segments of time temporarily behave in ways that seem to break the usual rules.

No Paradoxes Allowed

An important consequence of these quantum corrections is that history might remain self-consistent. Even if you attempted to do something that appears paradoxical — like destroying the time machine before it was built or sabotaging your grandfather’s marriage — the physical system would not settle into a final state that defies logic or causality. Instead, the universe would “correct” the scenario to avoid a permanent contradiction.

Scientists have been investigating such self-consistency arguments for decades. Some have posited that if time loops exist, something in the laws of nature would prevent paradoxes by ensuring that every event fits neatly into a coherent timeline (though this is speculative). This new research strengthens that argument by showing how, from the standpoint of thermodynamics and quantum mechanics, the loops might sustain themselves without derailing causality.

Despite these theoretical breakthroughs, many physicists still doubt that closed-timelike curves can occur in the real universe. Stephen Hawking famously championed the “[chronology protection conjecture](#),” which suggests that

fundamental physics — perhaps quantum gravity at the smallest scales — actively forbids true time loops from forming. Whenever conditions approach what is needed for a time loop, so the conjecture goes, the universe would intervene (possibly through intense radiation or singularities) and destroy that path.

How exactly it would do that is anyone's guess.

In fact, even whether such a cosmic safeguard actually exists remains an open question. Proponents of closed timelike curves note that rotating black holes, exotic forms of matter, or even certain cosmological models could, in principle, create the right environment for time loops. However, these ideas remain speculative without concrete experimental evidence.

Even if it turns out that time loops never take shape, studying them provides key insights into the deepest rules of reality. Understanding what happens to entropy, quantum phenomena, and relativity on such extreme curves helps physicists refine their theories of how the universe behaves under the most exotic conditions.

Moreover, attempts to model time-travel paradoxes can yield surprising discoveries relevant to other domains, such as the thermodynamics of black holes, the structure of quantum fields, or the nature of space-time near gravitational singularities. In some cases, research into [hypothetical time loops](#) has sparked ideas for quantum computing and cryptography, where “exotic” manipulations of information might be performed under special conditions.

For now, there is no definitive proof that time travel is physically attainable, much less that a person could step through a portal and visit ancient civilizations or witness their own birth. Yet the new study could be a pointed step showing that no fundamental law necessarily rules it out. By demonstrating how entropy and quantum fluctuations can ease or erase the contradictions on a time loop, Gavassino offers a potential blueprint for how the universe itself could make time travel self-consistent.

This does not mean practical time travel is on the horizon, not at all; but it does suggest that the idea isn't as impossible as it might seem at first glance. As research continues, both skeptics and enthusiasts will be watching to see whether nature truly permits such "bending" of reality — and, if so, what hidden laws protect us from the most perplexing paradoxes imaginable.

UFOs and the theoretical spacetime-bending technology behind them

March 13, 2020

Last year the US Navy confirmed that UFOs exist, meaning someone has access to advanced technology to build them. Declassified government research into warp drives provides insight into how UFOs could theoretically bend spacetime as a means of propulsion.

Slowly but surely, the confirmed existence of UFOs is entering the public consciousness.

[Leaked video footage](#) depicts Unidentified Aerial Phenomena (UAP) making seemingly impossible maneuvers while the Air Force pilots recording the craft looked on in wonder, literally shouting, "Wow! What is that, man? Look at that flying!"

We need to be talking about this more: "To the Stars Academy of Arts and Sciences, a group dedicated to pursuing research into UFOs and extraterrestrial life that was co-founded by rocker Tom DeLonge of Blink 182, helped bring attention to the videos."

More palatable, perhaps, than claiming these UFOs come from ETs, is the probability that they were built by humans as part of some black budget secret space program.

When you stop to think about the magnitude of what that actually means, you realize that there is advanced technology out there that is way beyond anything that is commercially available at present.

The Navy has confirmed that the UFOs seen in leaked video footage are real UAP, senators [have been briefed](#) on UFO sightings, and between 2007 and 2012 the Defense Intelligence Agency (DIA) spent \$22 million dollars on research into warp drives, antigravity, wormholes, extra dimension manipulation, and whole lot more!

“The warp drive involves local manipulation of the fabric of space in the immediate vicinity of a spacecraft” — Declassified DIA-funded research

As a thought exercise, let’s take a look at one of the 38 research papers that the DIA disclosed it had funded as part of its “[Advanced Aerospace Threat Identification Program](#)” called “[Warp Drive, Dark Energy and the Manipulation of Extra Dimensions](#).”

Therein it explains how an advanced technology could theoretically bend space and time around a craft as a form of propulsion called a warp drive — which doesn’t violate the cosmic speed limit.

“Physicists have discovered two loopholes to Einstein’s ultimate speed limit: the Einstein-Rosen bridge (commonly referred to as a ‘wormhole’) and the warp drive,” the paper reads.

“Fundamentally, both ideas involve manipulation of spacetime itself in some exotic way that allows for faster-than-light (FTL) travel.”

“A manipulation of spacetime itself in some exotic way that allows for faster-than-light travel” — Declassified DIA-funded research

According to the paper’s authors, Dr. Richard Obousy and Dr. Eric Davis, “If one is to realistically entertain the notion of interstellar exploration in time frames of a human lifespan, a dramatic shift in the traditional approach to spacecraft propulsion is necessary.”

In the paper, the authors back up the claim made by [Miguel Alcubierre](#) in 1994 that by manipulating extra dimensions, a warp drive could bend space around a craft by contracting space in front of it while expanding space behind it.

“The warp drive involves local manipulation of the fabric of space in the immediate vicinity of a spacecraft. The basic idea is to create an asymmetric bubble of space that is contracting in front of the spacecraft while expanding behind it,” the authors write.

By warping space and moving through time, the craft wouldn’t be in violation of the galactic speed limit — the speed of light.

“The ‘spacecraft ‘ remains stationary inside this ‘warp bubble’ and the movement of space itself facilitates the relative motion of the spacecraft” — Declassified DIA-funded research

Accelerating too fast will crush you and your craft from the G-Force, but keeping your craft in a warp bubble would eliminate the need — the need for speed.

This is one explanation why UAP would a more accurate description because these things wouldn’t really “fly” at super speeds so much as they would be warping time and space.

“Using this form of locomotion, the ‘spacecraft ‘ remains stationary inside this ‘warp bubble’ and the movement of space itself facilitates the relative motion of the spacecraft.

“The most attractive feature of the Warp drive is that the theory of relativity places no known restrictions on the motion of space itself, thus allowing for a convenient circumvention of the speed of light barrier,” according to the DIA-funded research.

$$\mathfrak{g} = \frac{v_{sh}}{c} \frac{x_{sh}}{r_{sh}} \frac{df}{dr_{sh}}. \quad (2.2)$$

The $\mathfrak{g}$ behavior of the warp drive bubble provides for the simultaneous expansion of space behind the spacecraft and a corresponding contraction of space in front of the spacecraft. Figure 1 illustrates the $\mathfrak{g}$ behavior of the warp drive bubble geometry. Thus the spacecraft is enveloped within a warp bubble and can be made to exhibit an arbitrarily large faster-than-light (FTL) speed ($v_{sh} \gg c$) as viewed by external coordinate observers. Even though the worldlines inside the warp bubble region are spacelike for all external observers, the moving spaceship (warp bubble) frame itself never travels outside of its local comoving light cone and thus does not violate special relativity.

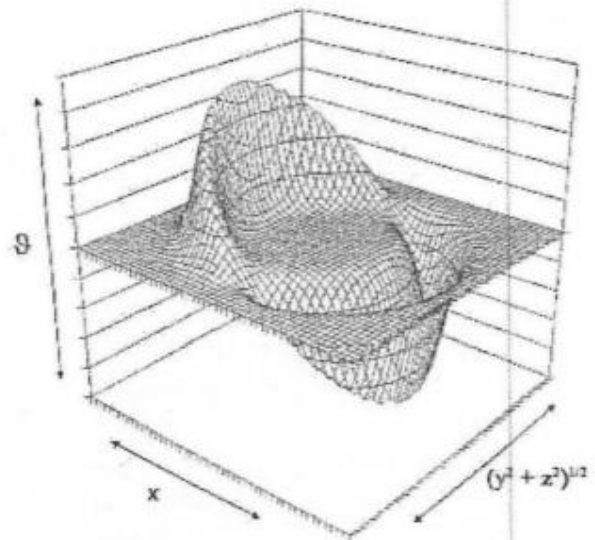


Figure 1. York Extrinsic Time ($\mathfrak{g}$) Plot

But in order for any of this to happen, one must have access to, and know how to use, very advanced technology. The paper talks about this technology in a theoretical sense, but can you imagine if the theory has already been put to the test and proven?

“The most attractive feature of the Warp drive is that the theory of relativity places no known restrictions on the motion of space itself” – Declassified DIA-funded research

Remember, UFOs exist, and we don’t know what technologies they use. This is one possible explanation.

According to the authors, the technology involved in a warp drive would have been able to manipulate extra dimensions in order to gain control of dark energy.

“If an advanced technology was able to influence the radius of an extra dimension, then it would acquire direct control over dark energy, and hence the expansion and contraction of space itself,” according to the paper.

Interestingly, “If one were to adjust the radius of the extra dimension in the direct vicinity of a spacecraft, then the dark energy density would also change only in the vicinity of the spacecraft, as would the expansion of space.”

The authors point out, “It is important at this point to appreciate that globally, the universe would continue to expand at the rate we observe today, but that only in the proximity of the spacecraft would space be “stimulated” to expand at some modified rate.”

The researchers concluded back in 2010 that “As tremendous a feat as this may sound, at this early stage in the research it is one of the only viable mechanisms to generate a warp drive.”

“UFOs are not in fact UFOs at all; they are time machines. And they aren’t made by aliens; they’re made by humans in the future — the very near future”
— Austin Steinbart

The seemingly impossible maneuvers of UFOs can be explained if you think of the UFO as a time machine instead of something being propelled at great speeds.

[According to Austin Steinbart](#), who claims on his YouTube channel to have begun working for the DIA at the age of 17, “UFOs are not in fact UFOs at all; they are time machines. And they aren’t made by aliens; they’re made by humans in the future — the very near future.”

Steinbart says that the military has been ordered to ignore UFOs since the 1950s in order to avoid an “adverse Butterfly Effect.”

Whether you believe Steinbart or not, his assertion that UFOs are time machines has been made by others, and it correlates the theoretical research funded by the DIA — only Steinbart claims that the research is operational and has been for some time.

Michael Masters, professor of biological anthropology at Montana Tech, also made the claim in his book, “Identified Flying Objects: A Multidisciplinary Scientific Approach to the UFO Phenomenon,” that many UFOs are actually made by humans in the future, [whom he calls “extraterrestrials.”](#)

Although scientists say that warp drives are theoretically possible, “further advances in quantum physics, quantum mechanics and metamaterials” are still

needed to make them a reality, [according to Joseph Agnew](#) – an undergraduate engineer and research assistant from the University of Alabama in Huntsville’s Propulsion Research Center (PRC).

Whatever you want to call them, the existence of UAP has publicly been confirmed by the US Navy.

Somebody made them, and spacetime-bending warp drives are just one component of a whole slough of government research into the subject.

It gets even crazier when you start looking at government research into stargates, wormholes, and antigravity!

TIME TRAVEL

Nov. 18, 2024



Scientists are uncertain whether cosmic strings exist, but if they do, these mysterious structures could revolutionize our understanding of the universe—and even make time travel possible.

If physicists can confirm the existence of cosmic strings, they may pave the way to achieving the “Holy Grail” of physics: a unified theory that combines quantum mechanics with Einstein’s general theory of relativity. Beyond this, cosmic strings could hold the key to bending spacetime and enabling time travel.

Theoretical models suggest cosmic strings are extraordinarily thin, far smaller than the nucleus of an atom, yet immensely massive—equivalent to tens of thousands of stars.

These long, thread-like structures are believed to either stretch infinitely across the universe or form closed loops. As they oscillate and gradually shrink, they emit gravitational waves. A typical loop of a cosmic string might span 10 to 20 light-years. Physicists theorize the existence of two types of cosmic strings.

Cosmic Superstrings: Rooted in string theory, these strings are thought to be stretched throughout the cosmos.

String theory posits that the fundamental particles of the universe are tiny, vibrating strings, and it strives to develop a “theory of everything.” Superstrings could offer insights into the fabric of reality and might even provide a mechanism for time travel.

Relics of the Early Universe: These cosmic strings are hypothesized to have formed during the universe’s earliest moments, as it cooled after the Big Bang

During this period, the four fundamental forces—gravity, electromagnetism, and the strong and weak nuclear forces—began to separate. This process may have created “cracks” in spacetime, leaving behind these structures, often referred to as the “hidden scars” of the universe.

Astrophysicist J. Richard Gott of Princeton University [suggests](#) that cosmic strings could unlock the secret of time travel. According to his theory, two cosmic strings moving near the speed of light could distort spacetime in such a way that they form a loop—a wormhole through which time travel might be possible.

Einstein's general theory of relativity allows for the possibility of spacetime curving back on itself, creating time loops. Gott theorizes that the immense gravitational pull of cosmic strings could bend spacetime into shortcuts, or wormholes.

For instance, if a spaceship traveled between two planets and encountered a cosmic string, it could traverse the distance far faster than light traveling in a straight line. This might allow the travelers to arrive at their destination before observing themselves leaving.

Furthermore, two cosmic strings moving in opposite directions and intersecting could create a time loop. By traveling along this loop, one could theoretically journey into the past.

Detecting cosmic strings, however, is extraordinarily challenging. Their extreme density should warp spacetime, causing a gravitational lensing effect that would make distant galaxies appear duplicated. Yet, if cosmic strings are lighter than expected, this lensing might not occur.

Gott proposes another detection method: observing gravitational microlensing events. These occur when a passing cosmic string briefly magnifies the brightness of a star.

Such observations could confirm the existence of cosmic strings and potentially lead to a Grand Unified Theory—a framework that unifies all known physics into a single, coherent model.

The question of whether time travel is theoretically possible remains a fascinating topic for scientists. The concept of time loops, as predicted by Einstein's theory of general relativity, has been a subject of interest in the field of dynamics.

As movies such as *The Terminator*, *Donnie Darko*, *Back to the Future* and many others show, moving around in time creates a lot of problems for the fundamental rules of the Universe: if you go back in time and stop your parents from meeting, for instance, how can you possibly exist in order to go back in time in the first place?

Physics student Germain Tobar from the University of Queensland in Australia has worked out a way to "square the numbers" to make time travel viable without paradoxes, reports [sciencealert.com](https://www.sciencealert.com).

Tobar's work suggests that space-time can potentially adapt itself to avoid paradoxes. For example, if a time traveler journeys into the past to stop a disease from spreading, the disease would still escape some other way, removing the paradox. This work is not easy for non-mathematicians to understand, but it looks at the influence of deterministic processes on an arbitrary number of regions in the space-time continuum and demonstrates how both closed time-like curves can fit in with the rules of free will and classical physics.



[Physicists Explore a Possible Breakthrough for Time Travel](#)

Physicist Fabio Costa from the University of Queensland supervised the research, which smoothed out the problem with another hypothesis that time travel is possible but that time travelers would be restricted in what they did to stop them creating a paradox.

In this model, time travelers have the freedom to do whatever they want, but paradoxes are not possible.

While the numbers might work out, actually bending space and time to get into the past remains elusive. The time machines that scientists have devised so far are so high-concept that they currently only exist as calculations on a page.

If we do get there one day, this new research suggests that we would be free to do whatever we wanted to the world in the past: it would readjust itself accordingly.

Time Travel is one thing which has been regulated to the realm of science fiction for decades, but recently prominent physicists, including such names as Steven Hawking, have seriously been considering the possibility and impossibility of time travel. What is the current scientific consensus on the issue of traveling through time? Will we all soon be able to hop in our own personal DeLorean rigged with flux capacitors and start reeking havoc in the past and future? What does science say about this seemingly paranormal fantasy?

Traveling to the past is perhaps the more romantic of the two time voyages. Being able to go back and observe primitive man or now extinct creatures has long been a fantasy of many biologists. While, others would love to go back in time to a famous event and personally experience it. Still others have a more personal reason for fantasizing about being able to travel into the past and that is getting the opportunity to see deceased loved ones again. It is a wonderful sounding idea but is time travel into the past possible?

And what of the future? While maybe a bit less romantic than traveling to the past, curiosity is enough to fuel the longing for traveling into the future. Getting to see at what point human civilization is at one hundred years from now or if humans still even exist is enough to get

most excited about this fantastic idea. Is traveling to the future possible?

Some have speculated that if one could travel faster than the speed of light traveling back in time would become possible. If one were to send matter from one point to another faster than the speed of light then according to special relativity the matter would travel back in time. The problem is that there is no known way to transport matter at the speed of light.

It is far more likely that we could succeed in sending a message or signal back in time, but even this seems impossible as the only way this could be permitted is through harnessing tachyons. Tachyons are a hypothetical subatomic particle that is constantly traveling at the speed of light. The problem is science is not sure if tachyons actually exist. They only exist in theory and do not conflict with the mathematics of current physics models, but have not been seen or discovered.

Does this mean that harnessing the speed of light will not help us in our time traveling adventures? Actually, no. It is actually the most likely candidate for helping us get to the future.

There seems to be a speed limit in the world we live in. Nothing can travel faster than the speed of light, but objects can travel near the speed of light. Speaking hypothetically, say we build a vehicle that can travel near the speed of light. Time inside of the vehicle would be slower than time outside of the vehicle.

This is because the laws that govern the universe will not allow an object to move faster than the speed of light so the closer we get to that speed, the slower time will move in order to prevent that from happening. This means that if you were traveling near the speed of

light only a week or two would pass inside while the outside world would age a hundred years. All of this has complicated mathematics to back it up.

The draw back is that if you were planning a vacation to the future it would be a permanent vacation. The physics and math will not allow you to reverse the process even if you threw your hypothetical time machine in reverse. In fact, doing that would bring you farther into the future. Plus, building a vehicle that can reach near the speed of light is impossible given our current technology.

We know that there is nothing in physics that says we cannot travel into the future. In fact, the laws of physics dictate that it is absolutely possible to travel into the future if one were able to reach near light speed, but what about the more romantic of the two, traveling into the past. We have previously illustrated that light speed will not help us get to our destination. Is there some other way that we can reach the past?

Open a photograph on your computer. Any photograph. Given today's technology the photo is probably very clean and crisp looking. Now take the magnifying glass tool that should be located somewhere within your picture viewing software and zoom in as much as you can.

What happened to your picture? It got pixilated didn't it? You may even be able to see the tiny spaces between said pixels depending on how close your software allows you to zoom. What is true for that photograph is true for everything in the universe. Zoom in close enough and everything is pixilated. The pixels, in the case of the universe, are atoms and subatomic particles, but just like the photograph there is also space between these cosmic pixels. Physics says that the same thing is also true for the fourth dimension, time.



Suppose we take our magnifying glass tool and zoomed in on time. We zoom in so close that we move beyond the realm of atoms and molecules and into an area that physicists call the quantum foam. Here we will find holes in time called wormholes. These holes in time can link two separate places and even two separate times together. It may be easier to imagine time as a blanket. Zoom in on the blanket and you will find wholes in the threading, these wholes lead out to the other side of the blanket. The same can be said for time except the wholes will lead to a different time and different space.

These wormholes are of course very tiny. No human could pass through them, unless some sort of new technology is discovered that could enlarge wormholes. This would allow humans to travel into the past. Unfortunately, technology like this is not going to come about in the near future and may never come about at all. This still is not the biggest problem for would be travelers to the past. There is a much larger dilemma, the paradoxes that are created by traveling to the past.

I do not want to be cliché so I am going to avoid the very popular "grandfather paradox" and instead use an example often used by the

great thinker and physicist Steven Hawking. Say a person somehow enlarges a wormhole. The other end of the wormhole leads one minute into the past. This person begins to assemble a gun and points it at the wormhole. He fires into it.

The bullet soars through the wormhole and comes out one minute into the past; the bullet connects with the past version of the person killing him before he even has the chance to assemble the gun. So how did the past version get shot if he died before assembling the gun? It is a paradox, causes have to happen before effects and traveling into the past would destroy this idea, which is impossible. This along with some other complicated ideas like radiation feedback cause traveling to the past to be near impossible, in theory, anyway. Human beings, though, are a resilient bunch. We have come a long way in a very short period of time and are determined to make the things we want reality. Science currently dictates a trip to the future is possible if and when the technology becomes available. Unfortunately, the consensus on traveling to the past is a bit murkier, but this universe is a bizarre one so never say never.

How the Universe's hidden 'scars' could unlock time travel

Nobody knows if cosmic strings exist, but if they do, they could change everything we know about the Universe.

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If the existence of cosmic strings is confirmed, it would be huge. They could help uncover the Holy Grail of physics: a theory of everything. And in the far future, they might even enable us to time travel.

The theories that predict their existence suggest that cosmic strings are thinner than an atomic nucleus. [Prof Ken Olum](#), of Tufts University, describes them as

astronomically long tubes. “They would most likely exist in the form of either loops or long strings that go on and on forever,” he says.

But while the strings are super thin, they can pack in a lot of mass. “A typical loop, which may be about 10–20 light-years long, can contain around the equivalent of the mass of tens of thousands of stars,” says Olum. But it’s thought they’d shrink over time as the tubes wiggle, radiating gravitational waves.

Confusingly, it’s also thought that there are two different types of cosmic strings, although they’d behave in very similar ways. One type, called cosmic superstrings, is predicted by string theory, an unproven attempt at a theory of everything, suggesting the Universe is ultimately made up of tiny, vibrating strings.

Cosmic superstrings would essentially be the fundamental strings that produce all the matter in the Universe, stretched out.

The other type is envisioned as a scar from the early Universe. At its earliest stage, the cosmos was in a completely different state from the one it’s in now. It was extremely hot and dense.

Physicists believe that the four forces of nature – electromagnetism, [gravity](#), and the strong and weak forces of the atomic nucleus – were merged into one single force at this point. But we don’t know much about the strange physics going on at the time.

After a period of cooling and extremely rapid expansion, known as inflation, the Universe changed ‘phase’ to become a very different place. This involved particles forming and the forces breaking off from each other.

Such phase transitions happen in water, as it freezes or evaporates. [J Richard Gott](#), professor emeritus of astrophysics at Princeton University, says you could think of the phase transition as a ‘melting’ of high-density energy in space. “When snow melts, you can be left with a few snowmen still standing,” he explains.

And that's, essentially, what cosmic strings are: areas of very high-energy density left behind during a cosmic transition from higher to lower energy.

Freezing is also a good analogy. If you fill an ice cube tray with water, you can see imperfections form while it freezes, including cracks and air bubbles. Cosmic strings would emerge in a similar way.

Physicists suspect cosmic strings could still be around today. However if we actually encountered one, which is unlikely, it might be unpleasant. A cosmic string travelling close to the speed of light and hitting Earth head-on would cut the planet in half, just like a wire cutting through a ball of clay. But one half would then immediately slam back into the other, according to [David Chernoff](#), a professor of astronomy at Cornell University.

In the best-case scenario, we could experience the equivalent of a magnitude 7 earthquake, says Chernoff. But it could produce a seismic event of up to around 12.6 magnitude – considerably bigger than the largest earthquake in history.

Searching the sky

The hunt is on to find cosmic strings. One approach is to look for spooky copies of the same galaxy or other bright objects. Because of their high density, the strings would cause gravitational lensing. This happens when heavy objects warp the space-time around them and alter the path of light as it passes by.

A cosmic string would bend space-time into a cone-like structure. So if we were looking at a galaxy from Earth and a cosmic string appeared vertically in front it, the light from the galaxy would be split – travelling on each side of the string. Meaning we should see two identical images of the same galaxy, a small distance apart.

There have already been reported sightings of this kind. In 2003, a team of astronomers reported the potential discovery of a cosmic string, but it was later proven that the two galaxies they had seen were not identical. Another such

claim was made last year. But Olum warns that recent research suggests this method of spotting cosmic strings is far from ideal.

Cosmic strings were originally thought to be much denser than scientists believe today, having what physicists call high tension, or mass, per unit length. In fact, they were once thought to be responsible for forming structures such as galaxy clusters by gravitational attraction.

However, observations by Olum and others suggest the strings should be fairly light. That's because very dense strings should cause certain anomalies in the cosmic microwave background, the light left over from the [Big Bang](#).

But those haven't been spotted, suggesting the strings, if they exist, must be about 10,000 times lighter than scientists initially thought. And they couldn't be the main cause of matter clumping together in the Universe. But it also means they'd warp space-time so subtly, that you wouldn't actually be able to see two distinct images of galaxies, due to the gravitational lensing.

Chernoff has come up with a more promising method of spotting them called gravitational *microlensing*. Instead of looking at galaxies, which appear as fuzzy objects, he wants to spot lensing by observing individual stars.

Star light, star bright

Chernoff's proposal involves looking at stars in the Milky Way and nearby galaxies and monitoring their brightness. The theory is, if a string passes between us and a star, the light from the star would be gravitationally lensed by the string.

For a short period of time, two unresolved images of the star would appear in the sky – though they wouldn't be separately discernible. But there would be a sudden and detectable doubling of the star's brightness. In fact, a string passing in front of a star should increase its brightness by a factor of two for a few days, before it goes back to normal, explains Chernoff.

While he's started investigating some data, he's yet to find a cosmic string. The approach is considered speculative. How likely we are to find strings this way will depend on how fast they're moving and whether they're clustered in galaxies – things we don't know for sure. But there's optimism among physicists. "This is an interesting idea," says Olum, a view supported by Gott.

Chernoff himself is cautiously optimistic. "We're actually in a golden age for this experiment," he says. "The National Science Foundation, NASA and ESA are building these experiments to do exactly what we need, which is to repeatedly measure the light from large numbers of stars."

He highlights the Vera C Rubin Observatory, currently under construction in Chile, as promising. It will allow us to make a time-lapse movie of the sky, looking at 17 billion never-before-seen stars.

The Vera C Rubin Observatory could be a vital tool in the search for cosmic strings.

If we do discover a string, the approach would be perfect for studying it. "Once you've detected a microlensing event, there's a whole bunch of other things that you can immediately do," says Chernoff, adding that the crucial advantage is that we'll know its exact location – pinpointed by an individual star. "So all the gravitational wave detectors could then be focused on a point in the sky."

The most promising data so far, however, comes from gravitational waves. Last year, the North American Nanohertz Observatory for Gravitational Waves, or NANOGrav, a collaboration between teams based in the US, Europe, Australia and China, reported evidence for a background of gravitational waves with long wavelengths.

These were spotted by observing pulsars, rotating objects that emit pulses of radiation at regular intervals. But gravitational waves with long wavelengths, such as those thought to be produced by cosmic strings, can warp space-time in a

way that makes the radiation from the pulsars irregular, allowing scientists to detect them.

The most likely explanation for the result is pairs of supermassive [black holes](#) orbiting each other as galaxies merge. That's because we know that black holes actually exist, unlike cosmic strings.

But is it the whole story? Long-wavelength gravitational waves kicking around in the galaxy may also come from other sources, including cosmic strings. The signal seen by NANOGrav may in fact be a cocktail of different types of gravitational waves.

When the team analysed the data, they were rather surprised. "The model of black holes doesn't fit well," says Olum who is part of the collaboration. The team went on to try and match the signal to various astrophysical sources and discovered that cosmic superstrings, the kinds predicted by string theory, fit the data well – better than black holes or the alternative type of cosmic strings.

The finding has led to a lot of excitement about the possibility that NANOGrav has discovered the first evidence for string theory. "We actually got a detection," says Gott. "That means we've seen something."

Olum remains cautious, however. "It could very well just be black hole binaries," he argues. "The next data set may show something different." Indeed, more data is likely to make the signal stronger and more reliable. But for that, we have to wait a few years.

Further ahead, the planned Laser Interferometer Space Antenna, LISA, will launch into space during the 2030s and continue the search for gravitational waves. "LISA is better matched to detect gravitational waves from cosmic strings than either NANOGrav or LIGO," says Chernoff.

The LISA probe could provide more telling evidence for the existence of cosmic strings.
Photo credit: Science Photo Library

Finding cosmic strings would be revolutionary – giving us important hints about what a deeper theory of physics would look like.

Not only may their detection give observational support for string theory, they might also provide a means to test so-called 'grand unified theories', which aim to describe the very young Universe, in which three of four fundamental forces (apart from gravity, you need a theory of everything for that) are united.

“There’s a huge number of grand unified models,” says Olum. “So even if we can just rule out some of them, that would help people know where to focus their attention.”

Cosmic strings could also help explain a series of recent, puzzling observations, including impossibly large black holes spotted by the James Webb Space Telescope. These beasts are so huge they must have grown faster than scientists thought possible. But it’s possible they may have been “seeded by the gravitational attraction of cosmic string loops in the early Universe,” says Olum.

The possibility of time travel

Could cosmic strings be practically useful? Scientists have long known that Albert Einstein’s theory of General Relativity allows loops in time to exist – possibly enabling time travel. This is because space-time can be curved until it closes in on itself and creates a loop.

Nobody has ever seen or built one, but such loops are a valid solution to Einstein’s equations. In 1991, Gott discovered that two moving cosmic strings could produce such a loop – and are an exact solution to the equations.

Heavy objects such as cosmic strings can bend space-time to create shortcuts in space-time. That’s ultimately what a wormhole is thought to be: a region connecting areas of space very far apart. “General Relativity says you can beat a light beam geometrically in a race if there’s a shortcut,” says Gott.

If you travelled between two planets, for example, and there was a cosmic string in the middle, this would create a shortcut compared with travelling straight between the points.

If you took this route and travelled near light-speed, you'd be able to arrive at your destination faster than a light beam travelling straight between the two planets. That means when you arrived at your destination, you'd be able to watch yourself packing your bags at your starting point.

Gott showed that two cosmic strings travelling in opposite directions, and crossing each other, would warp space-time in such a way that it would create a time loop. If you travelled around the two strings, you'd go back in time.

But this would require both the spacecraft and the strings to travel at 99.99 per cent of the speed of light, which is hard to achieve. And it's unlikely that a pair of infinite strings, which are rarer than loops, happen to exist in such close proximity.

"You're very unlikely to find an infinite string moving that fast in the observable Universe; they typically move at around half to 70 per cent of the speed of [light](#)," says Gott. "But the reason we're investigating this is we want to uncover clues as to how the Universe works."

"There's nothing wrong with his maths," says Olum, although he remains sceptical about the possibility of ever building a time machine. "If your Universe doesn't have this time machine already, you can't just take some matter and use it to make the cosmic strings proposed by Gott," he explains. "The strings would have to stretch across the whole Universe. So it's not very useful in terms of building a time machine."

The secrets of the Universe

Gott admits it would be hard to build a time machine in this way. But he believes there may be another way. Rather than using infinitely long strings, we could use

a finite string loop in the shape of a rectangle, with two very short sides and two enormously long sides (potentially thousands of light-years long).

The next step would be to let the loop collapse. "You can manipulate this loop by moving massive spaceships around it," he suggests, adding that "we're talking about super civilisations here."

This movement would stretch and drag the loop around until it collapsed into a black hole, bringing the sides towards each other at near light-speed. This would be an analogous situation to the time machine he presented in 1991, except that this time the solution wouldn't be exact, just approximate.

"So if your civilisation agrees to collapse a time loop around you, what you have to do in your spaceship is wait until the sides of the loop get close." And they could get very close – millimetres apart. You would then fly around the strings to visit your past.

There are downsides, though. "You'll find yourself trapped in a black hole, so you can't get back out to tell your friends about your adventures," he says. It would also be technically challenging. According to Gott, the time loop would need a mass corresponding to about half a galaxy.

The thought is dizzying. But to most physicists, including Gott, the alluring thing about cosmic strings isn't their potential for time travel. It's the fact that they may help uncover the secrets of the Universe on the most fundamental scales. Let's just hope one doesn't pass too close and slice Earth in half before we decode those hidden secrets.

About our experts

Ken Olum is a research professor of physics and astronomy based at Tufts University, Massachusetts. His research focuses on gravitational waves and cosmic strings and has been published in *Astrophysical Journal*, *Journal of Cosmology and Astroparticle Physics* and *Monthly Notices of the Royal Astronomical Society*.

J. Richard Gott is a professor of astrophysics based at Princeton University, New Jersey. He studies the General Theory of Relativity and his work has been published in *Monthly Notices of the Royal Astronomical Society*, *Astrophysical Journal* and *Physical Review*.

Prof David Chernoff is the chair of the Department of Astronomy at Cornell University, New York. His research focuses on cosmology and quantum physics and has been published in *Physical Review*, *Astrophysical Journal* and *Monthly Notices of the Royal Astronomical*.

Time Travel and Einstein's Theory of Relativity: Is It Possible?

Aug 19, 2024

Back to the Future time machine clock

Einstein's Theory of Relativity: A Brief Overview

Albert Einstein's theory of relativity, comprising the special and general theories, fundamentally changed how we understand the universe. Before Einstein, time was seen as absolute — flowing at the

same rate for everyone, everywhere. Space and time were considered separate entities. However, Einstein showed that time and space are interconnected, forming a four-dimensional continuum known as spacetime.

Special Relativity and Time Dilation

Einstein's special theory of relativity, published in 1905, introduced the concept that the laws of physics are the same for all non-accelerating observers, and that the speed of light in a vacuum is a constant — approximately 299,792 kilometers per second (about 186,282 miles per second) — regardless of the observer's motion. This theory led to the realization that time is relative, meaning it can pass at different rates for different observers depending on their relative velocity.

The Twin Paradox: A Thought Experiment

One of the most famous illustrations of time dilation in special relativity is the “twin paradox.” Imagine two identical twins: one stays on Earth, while the other travels on a spacecraft at a speed close to the speed of light. According to special relativity, time would pass more slowly for the twin in the spacecraft compared to the twin on Earth. Upon returning to Earth, the traveling twin would be younger than their sibling. This isn't just a theoretical idea — it's a real consequence of how time behaves at high velocities.

The Role of General Relativity

Einstein's general theory of relativity, published in 1915, expanded on special relativity by incorporating gravity. In general relativity, gravity is not seen as a force but as a curvature of spacetime caused by mass and energy. This theory predicts that time also slows down in strong gravitational fields — a phenomenon known as gravitational time dilation.

For example, a clock placed near a massive object like a black hole would tick more slowly compared to a clock far away from such an object. This effect, though small in everyday circumstances, becomes significant in the presence of extremely strong gravitational fields, like those near black holes or neutron stars.

Time Dilation and the Possibility of Time Travel

So, what does time dilation mean for the possibility of time travel? While Einstein's theories suggest that we cannot travel backward in time to revisit the past, they do open the door to a form of "forward time travel."

Traveling to the Future

If a person were to travel at a speed close to the speed of light, time would pass much more slowly for them than for those they left behind on Earth. Upon returning, they would find that while only a few years (or even minutes) had passed for them, many years could have passed

on Earth. This kind of time travel — moving forward into the future — is theoretically possible and is consistent with Einstein’s theory of relativity.

A real-world example, though on a much smaller scale, involves astronauts on the International Space Station (ISS). Traveling at about 28,000 kilometers per hour (17,500 miles per hour) relative to Earth, astronauts experience time just a tiny fraction of a second slower than people on Earth. This effect, known as “relativistic time dilation,” has been measured and confirmed through precise atomic clocks.

The Challenges and Limits

While time dilation offers a tantalizing glimpse into the possibility of time travel, there are significant challenges. The most obvious is the immense energy required to accelerate a spacecraft to near-light speeds. Currently, we lack the technology to achieve such velocities, and even if we could, the engineering challenges would be staggering.

Another limitation is that time dilation only allows for travel into the future, not the past. This means that once you’ve moved forward in time, there’s no way to return to your original moment. The idea of traveling back in time to change history or witness past events remains firmly in the realm of science fiction.

Wormholes: A Theoretical Bridge to the Past?

While special and general relativity suggest time travel into the past is impossible, some theoretical physicists have speculated about the existence of “wormholes” — hypothetical shortcuts through spacetime that could connect distant points in space and time. A wormhole might allow for travel between different times, but such structures remain purely speculative. They would require “exotic matter” with negative energy density to keep them open, and there’s currently no experimental evidence that wormholes exist or that they could be used for time travel.

Einstein’s Theories Proven: Time Dilation Confirmed

The concept of time dilation, as predicted by Einstein’s theory of relativity, has been experimentally confirmed numerous times. One of the most famous experiments involved flying highly accurate atomic clocks on airplanes around the world. When compared with stationary clocks on the ground, the airborne clocks were found to have experienced less time, confirming the predictions of special relativity. This experiment, known as the Hafele-Keating experiment, provided concrete evidence that time indeed slows down for objects in motion relative to a stationary observer.

Similarly, the effects of gravitational time dilation predicted by general relativity have been confirmed through observations of clocks on satellites. For example, the Global Positioning System (GPS) relies on precise timing provided by satellites orbiting the Earth. These satellites

experience both the effects of their high velocity and the weaker gravitational field at their altitude compared to Earth's surface. The onboard clocks run faster than those on the ground due to reduced gravitational time dilation but slower due to their velocity. Without correcting for these relativistic effects, the GPS system would quickly become inaccurate.

These confirmations not only validate Einstein's theories but also demonstrate that the effects of relativity are real and measurable, providing a foundation for understanding the nature of time and the potential for time travel.

Traveling Back in Time

While most scientific discussion on time travel focuses on moving forward in time, the idea of traveling backward — revisiting the past — remains a popular and provocative topic. Although Einstein's theories don't explicitly allow for backward time travel, some speculative concepts have been proposed.

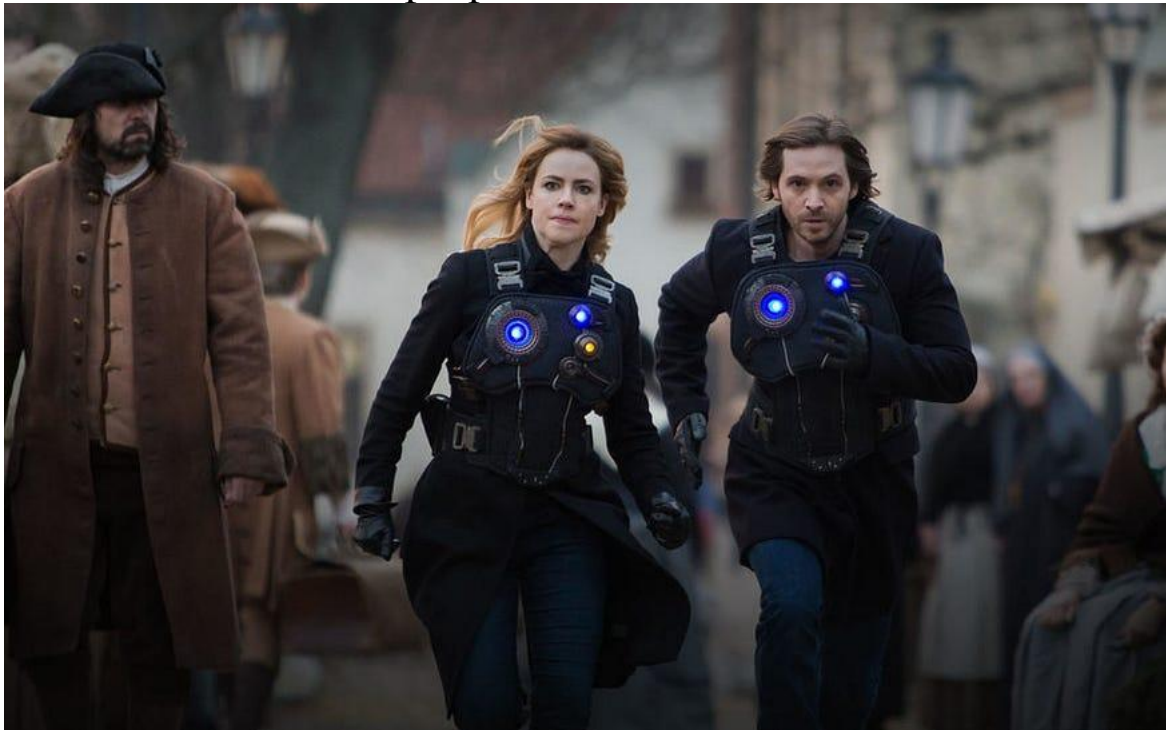
Cosmic Strings and Closed Timelike Curves

One such idea involves “cosmic strings,” theoretical one-dimensional defects in spacetime that are thought to have formed in the early universe. If two cosmic strings passed close to each other at high speed, they could theoretically create a “closed timelike curve,” which is a path through spacetime that loops back on itself. In theory, this could allow

for backward time travel. However, this remains a highly speculative and unproven concept.

The Grandfather Paradox

Another intriguing thought experiment related to backward time travel is the “grandfather paradox.” This paradox arises when a time traveler goes back in time and prevents their own grandfather from meeting their grandmother, thereby preventing the time traveler’s birth. The paradox raises questions about the consistency of events and whether the universe would allow such alterations to the timeline. Some theorists suggest that such paradoxes might be avoided if the universe self-corrects or if multiple parallel timelines exist.



A scene from 12 Monkeys TV series which is around the concept of paradox

Time Machines and Wormholes

Theoretical physicist Kip Thorne and others have explored the possibility of using wormholes as time machines. If a wormhole could be stabilized and manipulated, it might be possible to create a scenario where one end of the wormhole experiences less time than the other, potentially allowing for backward time travel. Again, this idea is purely theoretical and faces enormous challenges, such as the need for exotic matter to keep the wormhole open.

[Physics](#)

[Space](#)

[Time Travel](#)

Evolution Expert: Aliens are Future Humans & UFOs are Time Machines | Mike Masters

[Danny Jones Podcast](#)

In this episode, Dr. Michael Masters, a professor of biological anthropology, discusses his theory that UFOs and 'aliens' could be future humans traveling back in time to study their own evolutionary past. He explains the biological and evolutionary evidence that supports this idea, such as the consistent description of humanoid beings with exaggerated human traits like larger eyes and heads. He also explores the implications of this theory, like the possibility of future humans intervening in our past to preserve humanity or collect genetic material.

Masters delves into the science behind how these potential time machines could function, drawing from Einstein's theories of relativity and the idea of closed timelike curves. He examines cases where time seems to be manipulated around UFO encounters and abductions. The discussion also touches on topics like the nature of physical reality, religious influences from potential future human intervention, and the ethics of time travel.

Throughout the episode, Masters recounts his own experiences with strange phenomena, including instances of precognition and an encounter where he claims to have had information downloaded into his mind by an advanced non-local consciousness. He grapples with the profound implications of these experiences on his understanding of reality and consciousness.

Key Episode Takeaways

1. Dr. Michael Masters presents the theory that UFOs and 'alien' encounters are evidence of future humans traveling back in time to study their evolutionary past.
2. Masters grounds his theory in biological anthropology, citing accelerating trends in human evolution that could result in the 'alien' forms reported.
3. He examines how time travel could function based on theories of relativity and manipulating spacetime, potentially explaining UFO sightings and accounts of time dilation.
4. The discussion explores potential motivations for future human intervention, like collecting genetic material or preventing existential threats to humanity's existence.

5. Masters recounts his own strange experiences, including an incident where he claims information was downloaded into his mind by an advanced non-local consciousness.
6. The implications of the theory on topics like the nature of consciousness, religious history, and the ethics of time travel are also considered.
7. An open-minded yet scientific investigation of highly unconventional ideas around humanity's origins and destiny in the cosmos.

Top Episodes Quotes

1. *"Honestly, on the mark."* by Michael Masters

— This brief quote references Masters' own account of an encounter where information was seemingly downloaded into his mind, a profound experience that shapes his perspective on the phenomenon.

2. *"And then you look at Ingo Swann, his penetration book. He remote viewed it case after case of other abductees. I read one called abducted in the Latin Quarter by this woman that just sent me this book about her abduction experience. She was standing in this base crater in the moon with this woman who was telepathically communicating with her, looking down at this. Terry Lovelace claims to have seen this. This guy named Jerry Wills was taken up to this moon base and shown it and then brought back. He's like, what was the point of that? I just want to show you that there was a. You see enough of these, you start to ask questions."* by Michael Masters

— This quote references several alleged accounts of humans being taken to apparent bases on the Moon, which Masters connects to his theory of future humans operating in the past, showing his willingness to consider unconventional ideas.

3. *"Speaking of shit, that scared the hell out of you. That interview scared the hell out of me."* by Michael Masters

— This quote refers to Masters' reaction to a previous guest's discussion about the dangers of nuclear war, tying into the episode's exploration of future human motivations to potentially intervene in our past to prevent existential threats.

Chapter Details

Chapter 1: Introduction to Biological Anthropology



Dr. Michael Masters discusses his background in biological anthropology, focusing on hominin evolutionary anatomy, archaeology, and biomedicine. He explains his research premise that UFOs and 'aliens' could be future humans visiting their own evolutionary past.

- Dr. Michael Masters is a professor of biological anthropology researching the premise that UFOs and 'aliens' could be future humans.
- He specializes in hominin evolutionary anatomy, archaeology, and biomedicine.

Chapter 2: Evidence that Aliens are Future Humans



Masters presents various lines of evidence supporting his theory that the beings referred to as 'aliens' are actually future evolved humans. These include the highly consistent descriptions of humanoid forms, the fascination with human reproduction and genetics, and patterns observed in long-term abduction cases.

- The highly consistent descriptions of humanoid forms with human-like traits provides evidence they could be future evolved humans.
- Their fascination with human reproduction and acquiring genetic material from abductees suggests they are trying to ensure their own genetic diversity in the future.

1. *“Well, I mean, perhaps I'm biased in the sense that this is what I've been looking at since I was eight or nine. Like, I wasn't going and digging up bones and measuring them or anything back then, but I had sort of been thinking about this and obviously switched my major to study this.”* by Michael Masters

— This quote shows that Masters has been considering and researching this theory for most of his life.

Chapter 3: How Humans Will Evolve into 'Aliens'



Masters describes the major evolutionary trends in human evolution that project how we may appear in the far future, developing the large heads, large eyes, small bodies and other traits associated with depictions of 'aliens'. He explains how processes like paedomorphosis, craniofacial feminization and increasing brain size over millions of years could result in that form.

- Increasing brain size over millions of years could cause the eyes to expand outwards, appearing larger.
- Processes like paedomorphosis and craniofacial feminization could result in the skulls taking on the large head, small facial features associated with 'alien' appearances.

1. *“Yeah, no, that's a great question. The main thing, and I pointed this out in that 2012 medical hypotheses paper, too, one of the main reasons why the eye would grow larger is because our brains have grown larger throughout hominin evolution.”* by Michael Masters

— This quote directly explains why the eyes of future humans may become larger - due to increasing brain size causing eye expansion.

Chapter 4: Evolution of the Human Skull



Masters provides insights into the evolution of the human skull, explaining how the increasing brain size pushed the face inwards while the cranium expanded. He describes the developmental processes that allowed for significant brain expansion while constraining and reducing facial features over time, resulting in the iconic large head/small face contrast seen today.

- As the brain expanded massively over millions of years, it pushed out the face and cranium inwards, resulting in a more bulbous forehead and smaller facial features.
- This developmental constraint helped produce the iconic large cranium contrasted with a small face seen in modern humans.

1. *“Much, much smaller. 3.5 million years ago, they were a third the size of ours. They were about 420 cubic centimeters on average, the modern human brains, between 1416 hundred cubic centimeters. So about the third the size of our own.”* by Michael Masters

— This quote provides the striking statistics on the massive increase in brain size over human evolutionary history.

Chapter 5: Aliens' Fascination with Human Reproduction



The conversation explores the seeming obsession or fascination that the 'alien' beings have with human reproduction and acquiring genetic material, based on many reported accounts of abductions involving extraction of eggs/sperm and forced pregnancies. Masters analyzes the potential motivations behind this behavior if they are indeed future evolved humans.

- The 'aliens' obsession with extraction of human eggs/sperm and forced pregnancies could be an effort to increase their genetic diversity after future population bottlenecks.
- Problems like declining sperm counts and other issues impacting human reproduction today may compound for future humans, creating a need to revisit our genetic past.

1. *“So even outside of just the fact that we live in one island of Earth, an incestuous island of earth, that we are homogenized in our genome because of our culture, which we've always used to help our biology. It could actually hurt anyway, there's just a lot of reasons why they might want to come back and get our genes.”* by Michael Masters

— Here Masters summarizes some of the key reasons future humans may need to acquire genetic material from the past to increase diversity.

Chapter 6: Abduction Data Points



Masters examines various aspects of the data from reported 'alien abduction' cases that seem to corroborate the theory that they involve future humans. This includes the consistency of experiencers being told they are future humans, the patterns seen in lifelong abductees aging compared to the beings, and other commonalities across cases.

- While he hasn't quantified the exact percentages, Masters confirms that in many abduction cases the experiencers are directly told by the beings that they are future humans.
- Other patterns like lifelong abductees not seeing the beings age over decades of interactions also support the future human hypothesis.

1. *“Honestly, I would feel a little disingenuous giving an answer because I haven't really sat down and crunched those numbers.”* by Michael Masters

— This quote shows Masters being upfront that he doesn't have hard statistics on the exact percentages, though many cases seem to involve beings claiming to be future humans.

Chapter 7: US Government Involvement



The chapter explores the possibility that the US government and military forces are aware of and potentially working with the 'alien' future humans and their technology. Masters cites claims from insiders about reverse-engineering programs and the Rendlesham Forest case as potential evidence.

- There are claims from insiders like Dan Burisch about being involved in reverse-engineering programs working with future human beings and their technology.
- With more whistleblowers coming forward, Masters argues the evidence of some sort of government knowledge or collaboration with future humans needs to be considered seriously.

1. *“You have people like Dan Burrish, who claims to have been a part of these. He was, I guess, sampling this j rod individual from some, and who claimed to have been future human from some 45 or 55,000 years in our future.”* by Michael Masters

— This quote references the Danny Burisch claim about sampling a future human called the 'J-Rod' as part of a secret program.

2. *“So, yeah, you look at all of this, even going back ten years, that would sound like nonsense right now with grush and his testimony and everything else, you kind of have to start putting all of these pieces together and looking at them holistically, like maybe there's something to this.”* by Michael Masters

— Masters suggests that with more insiders like Dan Burisch coming forward, the idea of government working with future humans can't be easily dismissed.

Chapter 8: Jesus Christ as a Time Traveler



Masters explores the idea that Jesus Christ and other religious figures could potentially have been time travelers or manifestations of higher consciousness sent back from the future to guide humanity's development. The conversation covers how modern interpretations of scripture may be incomplete or inaccurate compared to the actual intentions.

- Jesus Christ and other religious figures may have been time traveling future humans or higher conscious beings sent to guide humanity.
- Many seeming oddities of ancient cultural practices like cranial modification could be the result of deliberate influences by advanced time travelers on human development.

1. *“And even there was a study, Geertz and Girtz, in 1995, where they interviewed people. Why are you doing this? Because our ancestors were instructed by the gods to do it, is what they said. Who are these gods? The*

gods, if they're future humans, if they're aliens, whether they're future human or not, have big round heads. “ by Michael Masters

— This quote highlights accounts of ancient peoples claiming they practiced cranial modification due to instructions from 'gods', which Masters theorizes could have been future humans.

Chapter 9: Block Universe Theory and Time Travel Paradoxes



The discussion delves into the theory of the 'block universe' and how it relates to the possibility of backward time travel and resolving potential paradoxes. Masters explains how in this model, the past cannot be changed, only experienced by time travelers, avoiding grandfather-type paradoxes.

- In the 'block universe' model, all moments from the beginning to the end of the universe are fixed in a 4D block of spacetime.
- Traveling through time in this model does not actually change any events, as time travelers are simply experiencing the block as is, avoiding logical paradoxes.

1. *“So if you move between those, you're not changing anything, you're just connecting different parts of that block. It's also called landscape time, occasionally, because it's easier for us to factor out one dimension.”* by Michael Masters

— This highlights the key implication that in a block universe, traveling through time does not actually change anything, thus avoiding paradoxes.

Chapter 10: Interstellar Travel and the Need for Time Travel



The conversation examines the implications of interstellar space travel and the likelihood that mastery of backward time travel would also be required. Masters explains how the effects of extreme time dilation would mean travelers could not return to their original time without this capability, highlighting the potential motivations for developing time travel technology.

Relativity and Time Travel

“Gravitational waves will give us extraordinarily accurate representations of black holes, and their space-time.” – Kip Stephen Thorne

Let's take a look at it!

Of all the force fields, the gravitational field is the one man has known for the longest time. One of its fundamental and most important properties (which today goes by the name of the principle of equivalence) was recognized by Galileo at the beginning of the 17th century and its fundamental law was established by Newton towards the end of the same century. We will analyze the principle of equivalence in a while, but it is good to remember that this is one of the pillars of the theory of general relativity: At the base of everything, this is the key element according to which the gravitational field imparts the same acceleration locally on all bodies, given the equivalence between inertial mass and gravitational mass.



The gravitational force is still studied along with the other fundamental forces. The reason is that the gravitational force is extremely weaker if compared with the others, in the order of 10^{38} compared to the electromagnetic force, for example. Therefore, an experiment that aims to make gravitational measurements is disturbed by the presence of other forces, unless we consider very large mass bodies: In this case, the gravitational forces, which are only attractive and long range, reach a high value, while the other forces tend to become negligible because they have a short range of action, or because, being both attractive and repulsive, the net effect is of zero average.

The theory of general relativity predicts the existence of gravitational waves. The relative weakness of gravitational force has both experimental advantages and disadvantages. The disadvantage is the great difficulty of detecting it, as can easily be deduced from the considerations made above. The advantage is the fact that, once the sensitivity necessary to detect gravitational waves such as the current Virgo and LIGO experiments has been reached, a probe will be available to explore matter and, in particular, the Universe in its most hidden accesses. Gravitational waves are able to pass through large amounts of matter without almost losing their energy. The Virgo and LIGO experiments succeeded in detecting gravitational waves.

The gravitational wave information reflects the large-scale distribution of matter; unlike the electromagnetic ones which provide information on an atomic scale. And all of this makes it very difficult to model stellar-sized objects. The discovery of gravitational waves has characterized a new experimental phase in which their properties such as waveform, spectrum, intensity, polarization, and direction of origin will have to be studied. In a more distant future, when physicists have total control of the experiment, gravitational waves could be produced in a laboratory and used for practical purposes such as electromagnetic waves. In this case, we will need some gravitational field transmitting antennas. Is it possible that extraterrestrials are able to communicate with gravitational waves instead of electromagnetic ones? The search for gravitational waves is of fundamental importance for the understanding of the structure of the universe and its origin.

In 1905, Albert Einstein published an article in which he expounded the special relativity principle (RR) as a modification of the previous Galilean principle of relativity with the addition of the constancy of the speed of light. According to Einstein, space and time should no longer be considered absolute, separate entities. On the contrary, space and time are part of a single reality, 4-dimensional space-time. The extension of the RR goes under the name of the principle of general relativity (GR). The problem of defining the GR was complicated by the fact that the RR only spoke of the electromagnetic field while the other force field known at that time, the gravitational field, remained completely excluded. How can the gravitational field also be included in the theory?

Newton's gravitational field formula was known. It expresses the force with which any two masses attract each other. The gravitational force is a universal force that acts between all bodies, be they small or large. It is a very weak force that becomes appreciable only between bodies of great mass. Einstein devoted his life to solve

the problem with defining GR from 1905 to 1916 and solved it starting from a brilliant intuition on a very simple fact: All bodies “fall” with the same acceleration regardless of their mass (not considering the friction of the air and the fact that the earth rotates on itself). This phenomenon goes by the name of the principle of equivalence and expresses the fact that the inertial mass is equal to the gravitational mass, or that two bodies gravitationally attract each other with the same mass with which they react to any force, of any type. The principle of equivalence is the basis on which the GR is based. A gravitational field is then equivalent to a non-inertial frame of reference in which space-time is modified, influenced, curved by the masses that generate it. Thus, the non-inertial reference systems are incorporated in the theory as a generalization of the inertial ones in the presence of the gravitational field. The 4-dimensional space-time is thus perturbed and bent by the masses that generate the gravitational field. This means that the space-time of physical reality is not flat, i.e., it is not Euclidean. The rules of Euclidean geometry no longer apply. In a non-Euclidean space, for example, the sum of the angles of a triangle is other than 180 degrees. Real space-time is not Euclidean. This data may seem surprising because Euclidean geometry is well satisfied in common experience up to very significant distances. The curvature of space-time begins to be felt over very large distances. The concept of non-Euclidean space-time is very difficult to imagine because it is difficult for us to visualize spaces with more than 3 dimensions. The definition of the curvature of space-time occurs through Einstein’s equation, an extremely complex equation that is able to describe any type of gravitational field and even the universe as a whole. Einstein’s equation is:

$$R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R = \frac{8\pi G}{c^4}T_{\mu\nu}$$

where R_{ik} is the Ricci tensor, g_{ik} is the covariant metric tensor, R is the curvature (Ricci’s scalar), G the gravitational constant and T_{ik} is the energy-momentum tensor.

Ricci’s tensor and scalar provide an indication of the curvature of space-time. They are related to the metric tensor. The unknowns in Einstein’s equation are the g_{ik} and T_{ik} or the field and distribution of mass and energy. Due to its complexity, it is soluble exactly only in very few simple cases. When Einstein expounded the theory of general relativity, there was no experimental evidence that required a new theory of gravitational phenomena. The Einsteinian theory explained some small corrections which were amply confirmed: An example is the deflection of the

trajectory of light rays by large mass bodies. Subsequently, Einstein introduced the cosmological constant in order to obtain a static model and bring the universe back into equilibrium:

$$R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4}T_{\mu\nu}$$

In any case, there were studies that highlighted the structure of the homogeneous and isotropic universe but in continuous expansion. The cosmological constant has taken on various roles over time, attempting to explain this acceleration as a fluid identified as the density of matter in the universe. One accredited model is that of the vacuum energy predicted by [quantum mechanics](#).

In Einstein's equations, the energy-momentum tensor plays the role of source of the gravitational field and, in the case of a weak and stationary field, it represents the static mass distribution. We, therefore, think that when a mass distribution evolves over time, this variation must modify the field and the curvature of space-time. As in all interactions existing in nature, this variation cannot be detected instantaneously in all space, but it will be linked to the propagation with finite speed in space-time of a perturbation which will be called a gravitational wave. These are metric waves and when they propagate in spacetime, the geometry and thus the distance between the points in 4-dimensional spacetime changes over time. From the Einstein field equations, we have to derive the g_{ik} , i.e., to obtain solutions able to describe the gravitational field.

Gravitational-wave (GW) sources can be classified into 4 types based on the frequencies of the radiation. The first type of source emits waves in the frequency band from 2 to 10 Hz, and it is believed that the initial density for the turbulences associated with the inflation of the universe introduces a gravitational influence in this frequency band. The second type of sources are those with a "very low" frequency (from 10^{-7} to 10^{-9} Hz). The predicted sources are super-massive black holes. The third type sources, from 10^{-6} to 1 Hz, include the gravitational collapse of super-massive stars and cosmic gravity. Sources of the fourth type, high frequency from 1 Hz to 10 kHz, are the fusion of binary objects with stellar mass and supernovae. In general, heavier sources correspond to lower frequencies. And the same physical objects as they evolve can generate GW radiation at different frequencies.

A few years ago, the LIGO / Virgo experiment, or rather the LIGO / Virgo interferometer, detected the gravitational signal related to the collisions of two black holes, which occurred exactly one billion years ago. LIGO as well as its twin

Virgo in Italy is a Michelson interferometer. A laser beam is separated into two different beams. These two rays travel through two different optical paths and are made to interfere, producing interference fringes. Due to the passage of a gravitational wave that propagates in the direction perpendicular to one of the two paths, the length of one of the two arms varies, and thus a variation of the interference fringes is obtained and can be measured with a photodiode. One of the problems encountered is the statistical fluctuation in the number of photons emitted by the laser source. In order for a gravitational wave to be detected, it is necessary to build interferometers with arms of enormous length; to circumvent this problem, interferometers called multipasses with Fabry-Perot cavities are used, in which the effective length of the arms is increased by means of multiple reflections until the desired length is reached.

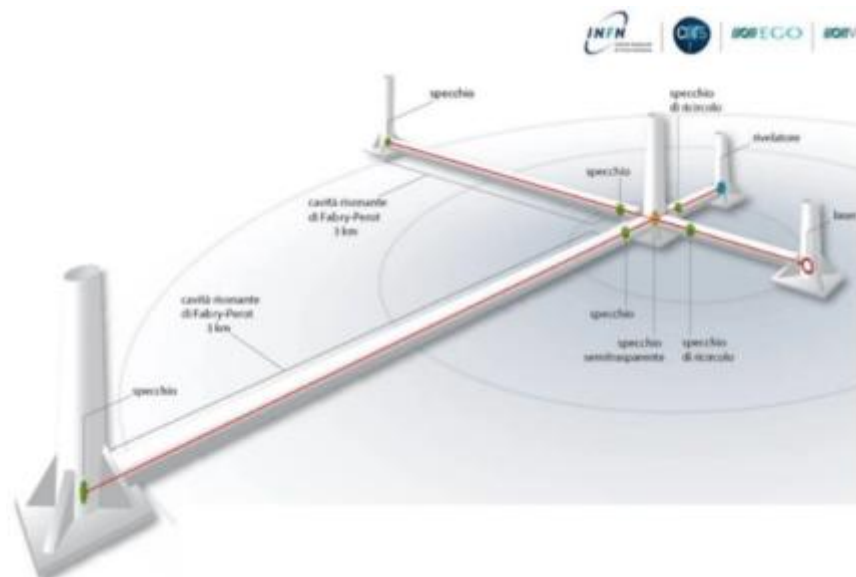
Different sources of noise can introduce spurious signals that can hide the gravitational wave. The main types of noise that perturb the measurement with the interferometer are: shot noise, due to the statistical fluctuation of the number of photons; Brownian noise of the mirrors, a residual pressure of the gas in the vacuum tube crossed by the laser beams which causes the refractive index to vary; seismic noise due to earthquakes. Some of them affect the position of the optical components (displacement noise), others are intrinsic noises of the reading system (phase noise). In any case, these noises affect the phase shift recorded by the photodiode at the output of the interferometer. The data recorded by a gravitational wave detector essentially consists of noise, from which it is necessary to distinguish the contribution of any and very weak signals of gravitational origin. This is the task of data analysis, which makes use of the theoretical foundations provided by Information Theory (detection of signals in the presence of noise) and the support of computers capable of performing sophisticated simulations.

An example of an implemented algorithm is the Kalman filter which allows to estimate the state of a system starting from the measured data. The algorithm consists of two processes: One makes a prediction of the state of the system, while the other optimizes the measurement based on the noise. Mathematically, it is something very simple, $X_{t+1} = F_t^* X_t + W_t$, where X_t is the state vector while the term W_t is the noise that defines the observability statistics. The optimality of the Kalman filter assumes that the errors are Gaussian. The story of the creator of this filter, Rudolph Kalman, is related to the mission to the Moon (Apollo mission) and addresses some problems about the impossibility of carrying out the mission safely, in particular the problem of recovering the capsule upon re-entry. The problem was this: Given a series of points such as radar tracks, and given the

dynamic model of the capsule's reentry, identify the most likely splashdown point and the area of scattering. Rudolph Kalman, a very young NASA researcher, presented a solution to this problem. But his solution was not initially regarded as the first. After other unsuccessful solutions were tested, the Kalman filter contributed effectively.

Let's go back to relativity.

According to the general theory of relativity, the intense accelerations of masses emit gravitational waves: That is, distortions of space-time that propagate at the speed of light. One billion years ago, two black holes collapsed sending a gravitational "shiver" across the universe: ripples in the fabric of space-time. LIGO and Virgo managed to measure it.



Michelson interferometer applied to Virgo and LIGO (Source: INFN)

In the scientific article cited at the end of the article, in the references section, it is indicated that the signal has an overall duration of the fraction of a second with a high value of statistical "certainty", thus confirming Einstein's theory but above all the existence of black holes, that is space-time passages. Then, measured energy was enormous, equal to about three solar masses (one solar mass is about 10^{30} Kg). The two black holes formed a binary system in rotation with each other with a mass that is 36 and 29 times that of the Sun (about 2×10^{30} Kg). They approached at a speed close to the speed of light and the collision produced a black hole releasing gravitational waves. The discovery made it possible to define the existence of black holes, whose existence would lead to many scientific reflections, starting from time travel. For science fiction lovers, that day could be a very special day, with the discovery of gravitational waves and perhaps with an in-depth knowledge about

space-time tunnels. Just remember how Marty and Doc traveled between “black holes” at 88 miles per hour.

We have all dreamed of traveling in time in the DeLorean, perhaps getting the Grays Sports Almanac to become millionaires like Biff Tannen in “Back to the Future Part II”. The “Back to the Future” trilogy would not have been possible without the invention of time travel. The scientific equation has calculated 88 miles per hour. It was the speed needed to reach quantum spacetime and fly into another time era. Time travel is obviously science fiction, although Professor Ronald Mallett, a professor of physics at the University of Connecticut, is convinced that one day we will travel in time. The personal tragedy of his father’s death from a heart attack when he was very young marked the beginning of the “timeline” adventure with a specific mission: go back in time, warn him of what was happening and try to save him.

Einstein’s special theory of relativity tells us that time is affected by speed. According to this theory, the time for a moving clock slows down. The faster the clock moves, the slower time slows down. This has been proven by many experiments. In particular, on a microscopic scale, there are subatomic particles that only live for a very short period of time and then disintegrate. When particle accelerators such as the Large Hadron Collider (LHC) at CERN in Geneva, Switzerland, accelerate these subatomic particles to a speed close to the speed of light, it turns out that the internal particle clock slows down, and the particles can live by 20 to 30 (or more) times longer than normal. This effect is technically called time dilation. On a large scale, this slowing down of time with speed was also demonstrated in an experiment that was done at the United States Naval Observatory. This experiment involved two atomic clocks. One of the clocks was held at the Naval Observatory, the other was put on a passenger jet that flew around the world at the speed of sound. When the clock on the passenger jet was compared to the clock at rest, it was found that the clock on the passenger jet had slowed down as Einstein had predicted. It should be remembered that the human heart is a clock. This means that the heartbeat behaves differently if a person tends to move fast. The person would not notice it, but a person at rest would notice it by looking at the heart rate of the moving person. The heartbeat and metabolism of the person moving on a rocket traveling at a speed close to the speed of light would slow down. If he or she had only traveled for a few years, many decades could have passed on earth on his or her return. He or she would discover that he or she had traveled to the future of the Earth. It is for this reason that Einstein’s theory of relativity predicts the possibility of time travel to the future.

The possibility of time travel is based on Einstein's general theory of relativity, developed in 1915. This is due to the prediction of the general theory of relativity that time is affected by gravity. According to this theory, the stronger the gravity, the more time slows down. This has been demonstrated experimentally and forms the basis of the GPS system, which takes into account the fact that clocks on the surface of the earth, where gravity is strong, are slower than clocks aboard satellites that are far above the earth, where gravity is weak. Theoretically, it has been shown that a rotating gravitational field, such as that of a rotating black hole, could allow for quantum perturbations that could lead to time travel even to the past. Time travel to the past could lead to paradoxes such as the grandfather paradox. If one travels back in time to prevent the grandparents from meeting, then the parents were not born and if the parents were not born, then one was not born. So, if you weren't born, how can you go back in time to stop your grandparents from meeting? It has been speculated that [quantum mechanics](#) can solve this paradox through the interpretation of many worlds or parallel worlds. According to the interpretation of parallel worlds, if you go to the past, you reach the past version of a parallel universe. In that parallel universe, you can prevent grandparents from meeting, but that doesn't affect the original universe you came from.

Light to matter could create a gravitational vortex that would alter time. Mallett idealized a tunnel-like laser machine to twist time. The professor was able to mathematically demonstrate that, by using a beam of laser light in circulation, it is possible to have a twist of space and time. I won't show the equation discovered by Mallett, but I recommend watching his videos on YouTube. Mallett's time machine can send information in the form of neutrons into the past / future. If the theory was valid, Ronald could only receive data from the future (and send it into the past), i.e., "activate" a timeline the moment it is turned on. Unlike the movie "Back to the Future", Mallett does not intend to be catapulted from one side to the other but to convey information on a timeline (similarly to the plot in the movie "Timeline"). Time travel fascinates us, and almost everyone would like to have the chance to go back and change something, defying one of the biggest unknowns in physics: time. Different time travel theories have taken different positions on the possibility of changing the past. There are three main theories: the theory of the multiverse, the theory of the dynamic timeline, and the theory of the fixed timeline.

We have all dreamed of traveling through time, if only for a minute, to have the chance to meet some of our ancestors. Maybe talk to him/her another time, listen to his/her teachings again. Suppose for a moment that you have a time machine

with the possibility of taking a trip, where would you like to go? Personally, I would like to go back to greet my grandparents with whom I spent the best moments of my life. Time is strange, it is certainly the most precious thing, and nobody knows what happens in the future. Nothing is written, maybe nothing happens by chance, so enjoy every moment and, as Doc said, “the future is not written but it can be created”.

Let's create a good one, then!

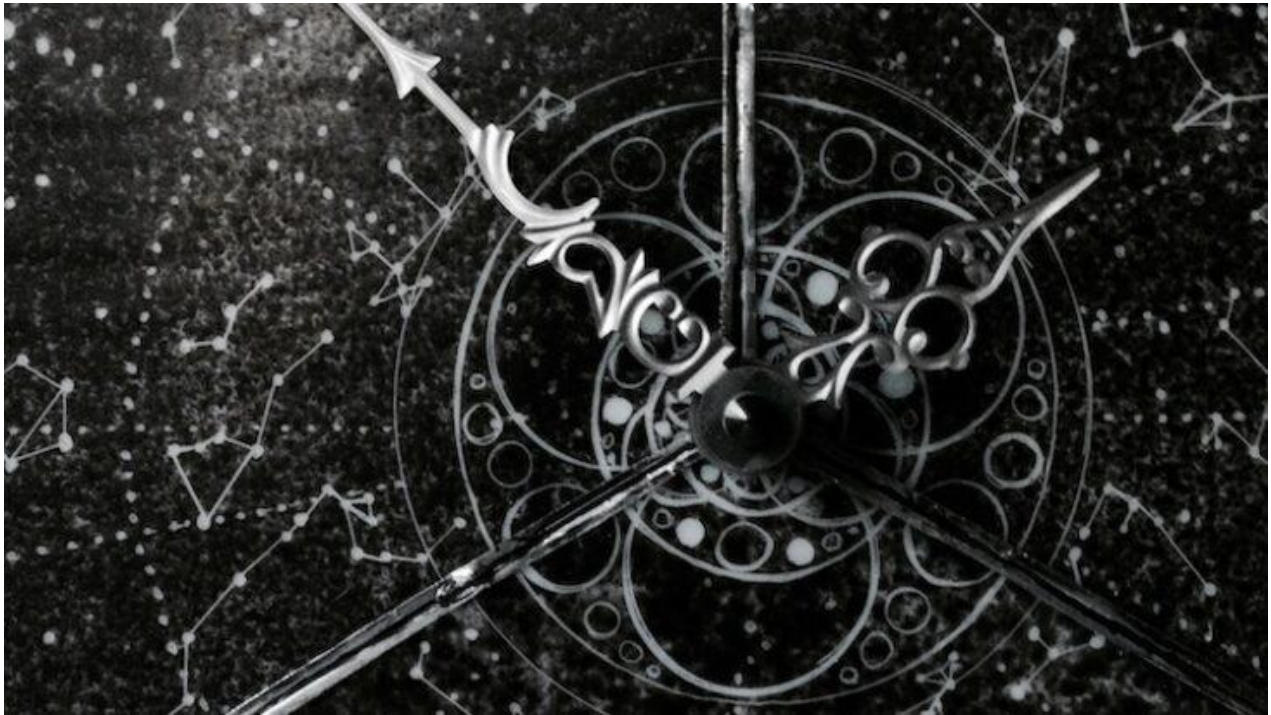
Another concept behind time travel is wormholes which theoretically connect two points in the universe. Entry from one end of the wormhole would almost instantly lead to exit from the other end, although these two points may be billions of light-years apart. It is not as simple as that. The problem is knowing how to get through it. These “tunnels” first appeared as a solution to Einstein's field equations. They are also called Einstein-Rosen bridges, named after Einstein and his then assistant Nathan Rosen.

The wormhole is constructed in such a way that one end could remain nearly motionless, while the other could move at almost the speed of light. Entering this wormhole would allow you to go back in time. A wormhole is basically a shortcut through space-time, so sending a pulse of light into it could allow for faster-than-light communication. Furthermore, according to the theory, the wormhole connects at least two points to a single throat, through which we could transfer matter to another point in space-time, or even to another dimension or universe according to some scholars, but this would require further theoretical and experimental research.

We can imagine space-time as something “pierced”: A hypothesis that involves the possibility of passing from one area of space-time to another, connecting parallel universes. This type of event could be very useful for controlling space-time. We can only live in the present, moving every second into the future, but slowly and without the slightest chance of returning to our past. A condition, impossible for the moment, is to be able to travel in space at the speed of light: It is the only way to slow down our clock and then, once back on Earth, find ourselves in the future. According to Kip Thorne and Michael Morris, CalTech physicists, the “wormhole” could be used to jump from one point in the universe to another, thus exceeding the speed of light. Does a “wormhole” connect two distant points in the universe or does it cross two parallel dimensions? We will have to find out.

In addition to the discovery of gravitational waves, an important demonstration of Einstein's general relativity is the set of Lunar Laser Ranging experiments. On the moon, there is a mirror. More than one, actually. The astronauts of the various Apollo missions have placed them on different points of the lunar surface. These mirrors, called retroreflectors, have a very useful feature. From any angle you look at them, the mirror sends back the observer's image. The reflectors have a diameter of 3.8 cm and are inserted into circular holes in the panel for thermal control. They were brought to the surface of the Moon 40 years ago and, over time, allowed us to know the orbit of the Moon with the accuracy of a few centimeters, to carry out multiple accurate tests of Einstein's Theory of General Relativity and important measurements of the internal structure of the moon.

The experiment (Lunar Laser Ranging, LLR) is conceptually very simple: It consists in sending a light signal (a monochromatic laser beam) from the Earth to the Moon's retroreflectors, measuring how long it takes to go back. A simple physics measurement. By knowing the speed of light and time, we can plot the distance which will be given by the speed of light multiplied by the travel time, divided by 2 as it is a round trip. One of the most interesting questions that the LLR tries to answer precisely is this: Is there a difference in the way the Earth and the Moon are attracted to the Sun? The signals are sent using a ruby laser that sends pulses of tens of nanoseconds, with energies of the order of ten joules per pulse and repetition times of 3 to 30 seconds. Each laser shot sends about 10^{17} photons to the Moon, but only one returning photon can be detected. For this reason, the laser is sent thousands of times. The return radius takes about 2 and a half seconds to return to the starting point; since the laser emits monochromatic light, the returning photons can be identified. But they are obviously too weak to be seen by the human eye. An instrument called a photomultiplier is used to amplify the signal. These measurements have led to relevant scientific results, such as the understanding that the Moon probably has a liquid core. It was also possible to verify the Theory of Relativity with remarkable accuracy: The Moon moves exactly as Einstein's equations predict. Mirrors on the Moon tend to degrade over time due to dust and the absence of the atmosphere. One day, they will have to be replaced with new mirrors to improve laser light-gathering efficiency. And then, we will need to take a new trip to the Moon.

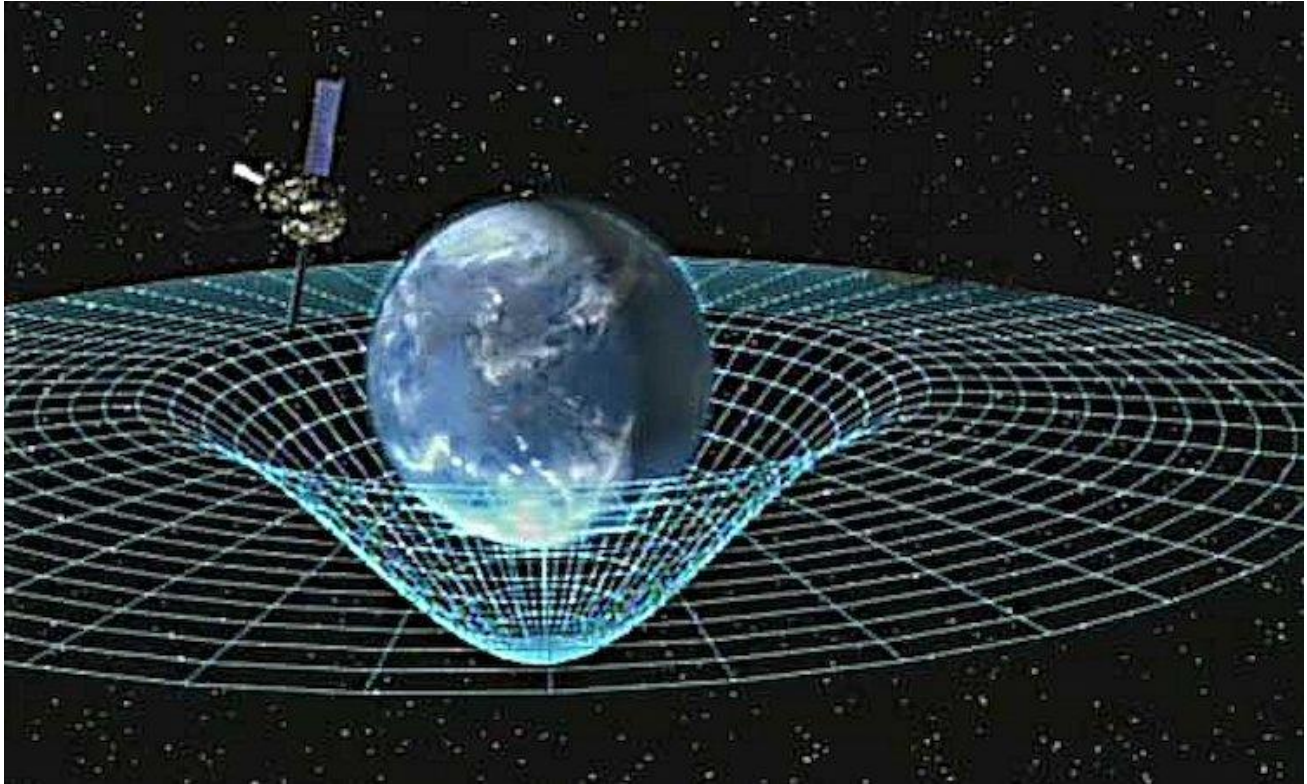


Time travel is possible, but it's a one-way ticket

The ability to travel through time, whether it is to fix a mistake in the past or gain insight into the future, has long been embraced by science fiction and debated by theoretical physicists. While the debate continues over whether travelling into the past is possible, physicists have determined that travelling to the future most certainly is. And you don't need a wormhole or a DeLorean to do it.

Real-life time travel occurs through time dilation, a property of Einstein's [special relativity](#). Einstein was the first to realize that time is not constant, as previously believed, but instead slows down as you move faster through space.

As part of his theory, Einstein re-envisioned space itself. He coined the phrase "spacetime," fusing the three dimensions of space and one dimension of time into a single term. Instead of treating space as a flat and rigid place that holds all the objects in the universe, Einstein thought of it as curved and malleable, able to form gravitational dips around masses that pull other objects in, just as a bowling ball placed in the centre of a trampoline would cause any smaller object placed on the trampoline to slide towards the centre.



A computer-generated representation of Einstein's curved spacetime. The Earth creates a gravitational dip in the fabric of spacetime which is deepest at its core. Courtesy and Â© of [NASA](#)

The closer an object gets to the centre of the dip, the faster it accelerates. The centre of the Earth's gravitational dip is located at the Earth's core, where gravitational acceleration is strongest. According to Einstein's theory, because time moves more slowly as you move faster through space, the closer an object is to the centre of the Earth, the slower time moves for that object.

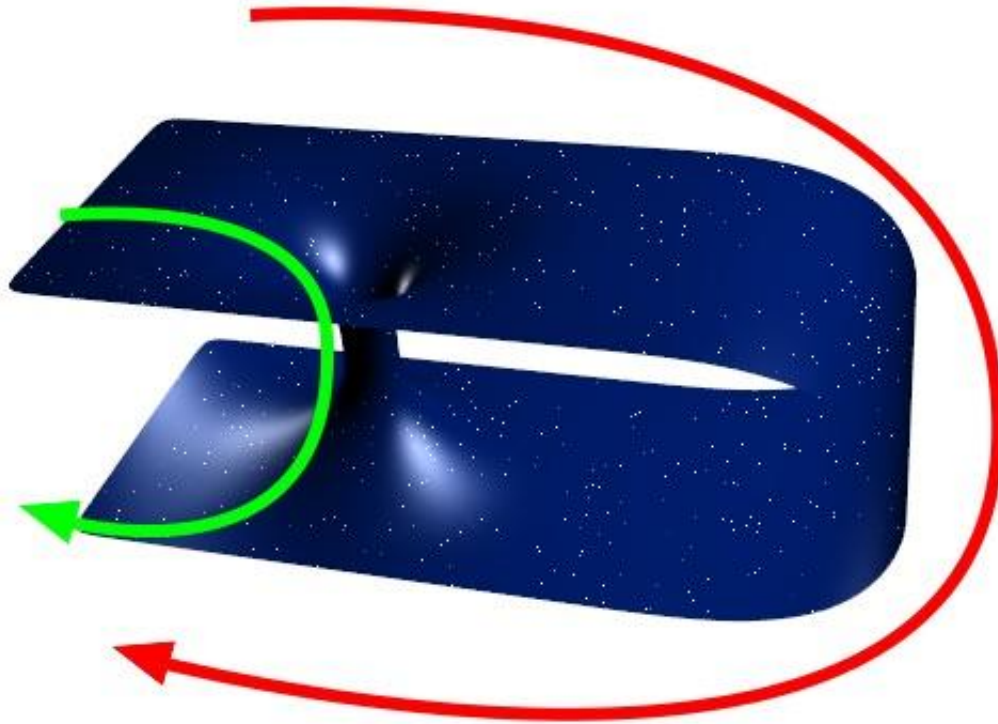
This effect can be seen in GPS satellites, which orbit 20,200 kilometres above the Earth's surface. These satellites have highly precise clocks onboard that gain an average of [38 microseconds per day](#) due to time dilation. While this time gain seems insignificant, GPS satellites rely on their onboard clocks to maintain precise global positioning. Running 38 microseconds fast would result in a positioning error of nearly 10 kilometres, an error that would increase daily if the time difference were not constantly corrected.

A more dramatic example of time dilation can be seen in the movie [Interstellar](#) when Matthew McConaughey and his crew land on a planet with an extreme gravitational field caused by a nearby black hole. Because of the black hole's intense gravitational influence, time slows dramatically for the crew on the planet, making one hour on the surface equal to seven years on Earth. This is why, when the crew returns to Earth, Matthew McConaughey's daughter is an old woman while he appears to be the same age as when he left.

So why hasn't humanity succeeded in making such drastic leaps forward in time? The answer to this question comes down to velocity. In order for humanity to send a traveller years into the future, we would either have to take advantage of the intense gravitational acceleration caused by black holes or send the traveller rocketing into space at [close to the speed of light](#) (about 1 billion km/h). With our [current technology](#), jumping a few microseconds into the future is all humans can manage.

But if technology one day allows us to send a human into the future by travelling close to the speed of light, would there be any way for the traveller to use time dilation to return to the past and report her findings? “Interstellar travel reaching close to the speed of light might be possible,” says [Dr. Jaymie Matthews](#), professor of astrophysics at the University of British Columbia, “[but] this voyage is one way into the future, not back to the past.”

If we can’t use time dilation to return to the past, does this mean that the past is forever inaccessible? Perhaps not. Einstein proposed that time travel into the past could be achieved through an Einstein-Rosen bridge, a type of wormhole. Wormholes are theoretical areas of spacetime that are warped in a way that connects two distant points in space.



A visualization of a wormhole: The fabric of spacetime curves back upon itself, forming a bridge between two distant locations. Image by [Panzi](#), CC-BY 3.0

Einstein’s equations suggested that this bridge in space could hypothetically connect two points in time instead if it were stable enough. “At the moment, even an Einstein-Rosen bridge cannot [be used to] go back in the past because it doesn’t live long enough – it is not stable,” Matthews explains.

“Even if it was stable, it [requires] other physics, which we don’t have. Hypothetical particles and states of matter that have “exotic” physical properties that would violate known laws of physics, such as a particle having a negative mass. That is why “wormholes” are only science fiction.”

While it would be fascinating to travel back in time to see the dinosaurs or to meet Albert Einstein and show him the reality of time travel, perhaps it is best if the past remains untouched. Travelling to the past invites the possibility of making an alteration that could destroy the future. For example, in [Back to the Future](#), Marty McFly travels to the past and inadvertently prevents his parents from

meeting each other, nearly preventing his own existence. But if he had undone his own existence, how could he have travelled back in time in the first place?

Marty's adventures are a variation of the grandfather paradox: what happens if you go back in time and kill your grandfather before your father is conceived? If you are successful, how is it possible that you're alive to kill your grandfather in the first place?

A [recent study](#) at the University of Queensland may have the answer to this baffling paradox. In this study, the researchers prove mathematically that paradox-free time travel is possible, showing that the universe will self-correct to avoid inconsistencies. If this is true, then even if we could travel back in time, we would never be able to alter events to create a different future.

While these new findings are enlightening, there appears to be more evidence that, although time dilation can allow us to glimpse the future, we will never be able to visit the past. As the late [Stephen Hawking](#) said in his book *Black Holes and Baby Universes*, "The best evidence we have that time travel [into the past] is not possible, and never will be, is that we have not been invaded by hordes of tourists from the future."

A beginner's guide to time travel

Learn exactly how Einstein's theory of relativity works, and discover how there's nothing in science that says time travel is impossible.

Everyone can [travel in time](#). You do it whether you want to or not, at a steady rate of one second per second. You may think there's no similarity to traveling in one of the three spatial dimensions at, say, one foot per second. But according to [Einstein's theory of relativity](#), we live in a four-dimensional continuum — space-time — in which space and time are interchangeable.

Einstein found that the faster you move through space, the slower you move through time — you age more slowly, in other words. One of the key ideas in relativity is that nothing can travel faster than the [speed of light](#) — about 186,000 miles per second (300,000 kilometers per second), or one light-year per year). But you can get very close to it. If a spaceship were to fly at 99% of the speed of light, you'd see it travel a light-year of distance in just over a year of time.

That's obvious enough, but now comes the weird part. For astronauts onboard that spaceship, the journey would take a mere seven weeks. It's a consequence of relativity called [time dilation](#), and in effect, it means the astronauts have jumped about 10 months into the future.

Traveling at high speed isn't the only way to produce time dilation. Einstein showed that gravitational fields produce a similar effect — even the relatively weak field here on the surface of [Earth](#). We don't notice it, because we spend all our lives here, but more than 12,400 miles (20,000 kilometers) higher up gravity is measurably weaker — and time passes more quickly, by about 45 microseconds per day. That's more significant than you might think, because it's the altitude at which [GPS satellites](#) orbit Earth, and their clocks need to be precisely synchronized with ground-based ones for the system to work properly.

The satellites have to compensate for time dilation effects due both to their higher altitude and their faster speed. So whenever you use the GPS feature on your smartphone or your car's satnav, there's a tiny element of time travel involved. You and the satellites are traveling into the future at very slightly different rates.

But for more dramatic effects, we need to look at much stronger gravitational fields, such as those around [black holes](#), which can distort [space-time](#) so much that it folds back on itself. The result is a so-called wormhole, a concept that's familiar from sci-fi movies, but actually originates in Einstein's theory of relativity. In effect, a [wormhole](#) is a shortcut from one point in space-time to another. You enter one black hole and emerge from another one somewhere else. Unfortunately, it's not as practical a means of transport as Hollywood makes it look. That's because the black hole's gravity would tear you to pieces as you approached it, but it really is possible in theory. And because we're talking about space-time, not just space, the wormhole's exit could be at an earlier time than its entrance; that means you would end up in the past rather than the future.

Trajectories in space-time that loop back into the past are given the technical name "closed timelike curves." If you search through serious academic journals, you'll find plenty of references to them — far more than you'll find to "time travel." But in effect, that's exactly what closed timelike curves are all about — time travel. There's another way to produce a closed timelike curve that doesn't involve anything quite so exotic as a black hole or wormhole: You just need a simple rotating cylinder made of super-dense material. This so-called Tipler cylinder is the closest that real-world physics can get to an actual, genuine time machine. But it will likely never be built in the real world, so like a wormhole, it's more of an academic curiosity than a viable engineering design.

Yet as far-fetched as these things are in practical terms, there's no fundamental scientific reason — that we currently know of — that says they are impossible. That's a thought-provoking situation, because as the physicist Michio Kaku is fond of saying, "Everything not forbidden is compulsory" (borrowed from T.H. White's novel, "The Once And Future King"). He doesn't mean time travel has to happen everywhere all the time, but Kaku is suggesting that the universe is so vast it ought to happen somewhere at least occasionally. Maybe some super-advanced civilization in another galaxy knows how to build a working time machine, or perhaps closed timelike curves can even occur naturally under certain rare conditions.

This raises problems of a different kind — not in science or engineering, but in basic logic. If time travel is allowed by the laws of physics, then it's possible to envision a whole range of [paradoxical scenarios](#). Some of these appear so illogical that it's difficult to imagine that they could ever occur. But if they can't, what's stopping them?

Thoughts like these prompted [Stephen Hawking](#), who was always skeptical about the idea of time travel into the past, to come up with his "chronology protection conjecture" — the notion that some as-yet-unknown law of physics prevents closed timelike curves from happening. But that conjecture is only an educated guess, and until it is supported by hard evidence, we can come to only one conclusion: Time travel is possible.

A party for time travelers

Hawking was skeptical about the feasibility of time travel into the past, not because he had disproved it, but because he was bothered by the logical paradoxes it created. In his chronology protection conjecture, he surmised that physicists would eventually discover a flaw in the theory of closed timelike curves that made them impossible.

In 2009, he came up with an amusing way to test this conjecture. Hawking held a champagne party (shown in his Discovery Channel program), but he only advertised it after it had happened. His reasoning was that, if time machines eventually become practical, someone in the future might read about the party and travel back to attend it. But no one did — Hawking sat through the whole evening on his own. This doesn't prove time travel is impossible, but it does suggest that it never becomes a commonplace occurrence here on Earth.

The arrow of time

One of the distinctive things about time is that it has a direction — from past to future. A cup of hot coffee left at room temperature always cools down; it never heats up. Your cellphone loses battery charge when you use it; it never gains charge. These are examples of [entropy](#), essentially a measure of the amount of "useless" as opposed to "useful" energy. The entropy of a closed system always increases, and it's the key factor determining the arrow of time.

It turns out that entropy is the only thing that makes a distinction between past and future. In other branches of physics, like relativity or quantum theory, time doesn't have a preferred direction. No one knows where time's arrow comes from. It may be that it only applies to large, complex systems, in which case subatomic particles may not experience the arrow of time.

Time travel paradox

If it's possible to travel back into the past — even theoretically — it raises a number of brain-twisting paradoxes — such as the [grandfather paradox](#) — that even scientists and philosophers find extremely perplexing.

Killing Hitler

A time traveler might decide to go back and kill him in his infancy. If they succeeded, future history books wouldn't even mention Hitler — so what motivation would the time traveler have for going back in time and killing him?

Killing your grandfather

Instead of killing a young Hitler, you might, by accident, kill one of your own ancestors when they were very young. But then you would never be born, so you couldn't travel back in time to kill them, so you would be born after all, and so on ...

A closed loop

Suppose the plans for a time machine suddenly appear from thin air on your desk. You spend a few days building it, then use it to send the plans back to your earlier self. But where did those plans originate? Nowhere — they are just looping round and round in time.

5 Ways to Travel Through Time

[A Journey Through Time](#)

Ever wondered how you could travel through time? If so, you're not alone, as numerous scientists are also preoccupied with this idea, and they even put a few experiments together to prove their theories.

1. Speed

This is probably the most pragmatic way to move through time. Einstein's theory of special relativity shows that whenever you travel at speeds close to the speed of light, time slows down in contrast with the outside world. It's not just a theory, since special measurements had already been done. With the help of two atomic clocks, one onboard a jet aircraft and the other stationary on Earth, physicists have proven that the moving clock was ticking slower, due to the traveling speed of the aircraft.

It wasn't much of a time altering since we're far off from achieving the speed of light, but if the craft traveled at 90% of the speed of light, the time would pass approximately 2.6 time slower than it would on the Earth. Of course, if we would push the speed even further, time would slow even more.

2. Gravity

This method is also inspired by Einstein. According to his theory of general relativity, the more intense the gravity, the slower time moves. For example, if you were to travel to the center of our planet, the gravity force would increase, making time pass slower than it would on the surface.

This effect has also been measured. In 2010, physicists at the US National Institute of Standards and Technology (NIST) put two atomic clocks 33 centimeters above the other, proving there was a slight difference between their ticking rate. The one above ticked faster because the gravitational force was lower, while the one below experienced a small ticking delay.

But how can we travel to the future using this method? We only need a region with extremely strong gravity, like a black hole. Whenever you approach its event horizon, time will move slower, but this is too risky for the moment, as scientists are yet to determine what lies beyond that.

In any case, if we had the technology to reach a black hole (the closest one being 3,000 light years away,) the time altering achieved through traveling would be far greater than what we would obtain by orbiting the black hole itself.

3. Suspended animation

Now we're talking about a more realistic way to achieve time travel , if we take into account our current technological means. Unlike the above mentioned strategies, the suspended animation will temporarily slow you perception of time by gradually lowering or stopping your body processes in order to be restarted at a later date. So instead of chasing after time travel, why not wait for it instead?

Bacterial spores are renowned for their ability to survive for millions of years in a variation of suspended animation, until the necessary conditions for life are met. At this point, they'll just restart their metabolisms once more.

Another example comes from the animal kingdom, where bears and squirrels can slow down their metabolism while they hibernate, drastically reducing the requirements of their cells when it comes to food and oxygen. But are humans able to do the same?

4. Wormholes

Because the Universe is so vast, it allows for certain shortcuts through spacetime so you can visit it faster. The wormhole acts as a bridge between two different points in the cosmos, providing a fast a reliable journey through billion of light years or more.

Numerous scientists, including Stephen Hawking, believe that wormholes are continuously appearing all around us, but only at a quantum scale, which is far lower than atoms. To make this viable for humans, we have to find a way to contain a wormhole and adjust its size so that we would be able to travel through it. Such a feat is doable...at least in theory.

5. Using light

Last, but not least, the idea put together by American physicist Ron Mallet points out that we could use a rotating cylinder of light to spin spacetime. At this point,

anything released inside the vortex of light would theoretically be sucked-up in space and time similar to how “a bubble runs around on top of your coffee after you swirl it with a spoon.”

Mallet explains that such an experiment could grant access to time travel, but time could go either way, meaning that you could end up either in the future or the past. After publishing his theory in 2000, Mallet has been trying to raise the necessary funds to bring his concept into reality. His plan aims at dropping neutrons through a circular device of spinning lasers.

Although his assumptions were neglected by the physics community because of a small glitch found in the basic model, his experiment is likely to work if the upcoming years will bring more understanding of the laser physics.



It is the general belief that UFOs and aliens originate from distant star systems and galaxies, and that they travel to the Earth using superior technology.

This theory is vastly accepted because we don't have such technology, and so we automatically believe that such objects must be driven by superior races from other planets. However, in my mind, this theory has fundamental flaws and inconsistencies which are outlined below:

1. Such flying objects have been seen in all shapes, sizes, and colors. It's as if the aliens can't make up their mind on which kind of vehicles to use. The traditional shape is the flat disk flying saucer.

Other shapes include cigars, spheres, pyramids, triangles, and many other shapes. They have been reported in many colors such as silver, white, orange, red, black and others.

The question here is this; if these objects come from distant stars, then why are the aliens using so much versatility? Or are we being visited by several species of aliens all of which use a different technology? If so why do their ships all look different, while the beings inside all look the same?

2. If these aliens are from distant stars then they must be very advanced. Why would such advanced beings visit the Earth for millennia and continue study us? Surely their advanced technology would allow them to collect what they need in only a short time. Why do they keep coming? And what could possibly interest them so much to keep them here for thousands of years?

3. Why don't they make contact with us? It has been suggested that contact with aliens would be the downfall of religion, and would provoke unprecedented disturbances in our societies. Contact with superior alien beings could only help mankind in every way.

We would not need to turn our back on religion, nor would we run in panic. This is because such advanced beings would know exactly how to introduce themselves, and how to assure us that we can only profit

and learn from them. So why are they hiding from us, and at the same time showing themselves just enough?

These are the basic problems I have with the alien race theory. And as we evolve and develop, we'll find it more and more difficult believing that UFOs visit the Earth from distant stars. This is not to say that alien races do not exist, on the contrary, I indeed believe that the stars are full of advanced civilizations, and that one day we'll make contact with them.



So what are UFOs?

I believe UFOs are man-made time machines, driven by human beings which have evolved into what we call aliens. They come from our distant future, and they use these vehicles to travel to their past. When we look at UFOs and the "aliens" who drive them, we're actually seeing

how evolution is going to change mankind, and we're seeing what technology mankind will one day possess.

Remember that in the future mankind will have technology which is far superior to anything we can possibly imagine today. It's highly feasible that in the distant future we'll even learn to control time. In fact, Albert Einstein's Theory of Relativity suggests that time distorts if an object travels at great speeds (faster than the speed of light).

Experiments have been conducted in this area and they indicate that the relativity theory is correct. Once we have time travel under control, where will we go? I think the first thing we'll do is travel back through Earth's history. We'll have the technology to travel to any point in time, we might for example, want to see who actually built the pyramids, and what happened to Atlantis.

But what will mankind look like in 500,000 years? Will we be exactly like we are now? Or will our bodies evolve to accommodate the drastic changes our high-tech future is bringing us. It's likely that we'll look exactly like reported aliens; long skinny arms and legs, large brainy heads, and pigment-free skin.

If you compare the look of our distant relatives who lived in caves to modern man and then project this trend, then you'll recognize that we're going to get thinner, weaker, and smarter. We will indeed look like aliens in the distant future. This theory has major advantages over others:

1. UFOs are seen in all varieties because they all originate from a different point in future time, so each type originates from a specific technological point in time. The saucer shaped UFOs might be from the 22 Century, the cigars from the 23 Century, the spheres from the 24 Century, etc.

We see various kinds of objects originating from various points in man's future. One could compare this to the advancing developments in the automobile industry – each technological revolution has created a different looking automobile because the design must accommodate the technology and advancing ergonomics.

2. The time travelers don't make contact because that would distort the time continuum, and could cause time to split. The outcome of a major time split could be devastating and very difficult to "clean up." So it might be best for all not to make contact, and that's probably why they don't.

All this is based on one simple logic; if time travel will ever be possible then the result will be someone actually doing it. This means that if they travel back in time we will see them in our time (if they do not hide from us).

And that's exactly the point – they might have technology to travel back in time but not to be invisible, or at least on the first attempts. And I believe they will have to travel in some sort of vehicle. So the end result is extremely advanced human beings appearing in some kind of vehicle – and to me this completely explains UFOs and "aliens".

Other Theories

This leads me to "déjà vu," a feeling many people experience from time to time which is described as "A feeling that I have already relived this moment". This could in fact be the result of a local time split. We don't actually relive a moment – instead, it's two realities running parallel but slightly unsynchronized. For a moment, everything around you exists twice, the original reality, and distorted reality which is slightly different due to a time split. Many time splits may be caused

by time travelers contaminating and slightly changing events. And I believe they possess technology which prevents things from getting out of control – a sort of vacuum cleaner for time.

However, time splits are unavoidable and they might be responsible for many unsolved mysteries such as déjà vu and things “disappearing” like in the Bermuda triangle area. Many of the documented unexplainable mysteries might be the result of time splits.

Much has been written about the paradoxes of time travel, and I would like to give some of my views on the subject. Paradoxes exist because we don’t (yet) have the capacity to really understand the concept of how time actually works.

To be able to understand time, we need to look at the Universe in a totally different light – I mean in a completely different way. I believe the biggest error many of us are making is believing that time is linear (a start, a middle, and an end). I don’t believe this is the case at all. I believe time (as we understand it) does not exist at all – all events that have ever happened and ever will all happen at the same time! It’s our perception of time that makes us think otherwise.

Imagine for a moment a piece of music on a CD. We listen to the music in a linear way (from start to end), but the music is indeed stored on the media in a nonlinear way, and all the digital information on the CD exists at the same time and there is no beginning and no end. Our perception (the CD player) “serves” the music bit by bit. It is quite feasible that time conceptually works in exactly the same manner.

I’m afraid that traveling through a traditional linear time model would be very difficult to achieve. The reason is that time presented in such a

way is nothing more than the matter of the Universe arranged in a certain way at a certain moment, and to travel through such time one would have to rearrange the matter to reflect a specific point in time. Whereas the nonlinear approach does not involve matter at all. Additionally, the nonlinear approach completely does away with questions like “when did time start,” and “how can it continue forever” – time simply exists all at the same time.

But it may well be that the Universe is also nonlinear, and it’s only our perception that gives us a feeling of space depth. If the two systems (space and time) are both nonlinear, then to me, that explains almost all of the mysteries of existence – everything we experience including time and space is nothing more than a perception of something that in reality is quite simple.



Time travel: Is it possible?

February 24, 2024

Science says time travel is possible, but probably not in the way you're thinking.

Is time travel possible? Short answer: Yes, and you're doing it right now — hurtling into the future at the impressive rate of one second per second.

You're pretty much always moving through time at the same speed, whether you're watching paint dry or wishing you had more hours to visit with a friend from out of town.

But this isn't the kind of time travel that's captivated countless science fiction writers, or spurred a genre so extensive that [Wikipedia](#) lists over 400 titles in the category "Movies about Time Travel." In franchises like "[Doctor Who](#)," "[Star Trek](#)," and "[Back to the Future](#)" characters climb into some wild vehicle to blast into the past or spin into the future. Once the characters have traveled through time, they grapple with what happens if you change the past or present based on information from the future (which is where time travel stories intersect with the idea of [parallel universes](#) or alternate timelines).

Although many people are [fascinated by the idea](#) of changing the past or seeing the future before it's due, no person has ever demonstrated the kind of back-and-forth time travel seen in science fiction or proposed a method of sending a person through significant periods of time that wouldn't destroy them on the way. And, as physicist [Stephen Hawking](#) pointed out in his book "[Black Holes and Baby Universes](#)" (Bantam, 1994), "The best evidence we have that time travel is not possible, and never will be, is that we have not been invaded by hordes of tourists from the future."

Science does support some amount of time-bending, though. For example, physicist [Albert Einstein](#)'s [theory of special relativity](#) proposes that time is an illusion that moves relative to an observer. An observer traveling near the [speed of light](#) will experience time, with all its aftereffects (boredom, aging, etc.) much more slowly than an observer at rest. That's why astronaut [Scott Kelly](#) aged [ever so slightly less](#) over the course of a year in orbit than his twin brother who stayed here on Earth.

There are other scientific theories about time travel, including some weird physics that arise around [wormholes](#), [black holes](#) and [string theory](#). For the most part, though, time travel remains the domain of an ever-growing array of science fiction books, movies, television shows, comics, video games and more.

ALBERT EINSTEIN'S THEORY

Einstein developed his theory of special relativity in 1905. Along with his later expansion, the [theory of general relativity](#), it has become one of the foundational tenets of modern physics. Special relativity describes the relationship between space and time for objects moving at constant speeds in a straight line.

The short version of the theory is deceptively simple. First, all things are measured in relation to something else — that is to say, there is no "absolute" frame of reference. Second, the speed of light is constant. It stays the same no matter what, and no matter where it's measured from. And third, nothing can go faster than the speed of light.

From those simple tenets unfolds actual, real-life time travel. An observer traveling at high velocity will experience time at a slower rate than an observer who isn't speeding through space.

While we don't accelerate humans to near-light-speed, we do send them swinging around the planet at 17,500 mph (28,160 km/h) aboard the [International Space Station](#). Astronaut Scott Kelly was born after his twin brother, and fellow astronaut, [Mark Kelly](#). Scott Kelly spent 520 days in orbit, while Mark logged 54 days in space. The difference in the speed at which they experienced time over the course of their lifetimes has actually widened the age gap between the two men. "So, where[as] I used to be just 6 minutes older, now I am 6 minutes and 5 milliseconds older," Mark Kelly said in a panel discussion on July 12, 2020, [Space.com previously reported](#). "Now I've got that over his head."

GENERAL RELATIVITY AND GPS TIME TRAVEL



This not-to-scale image shows the constellation of GPS satellites whizzing around the Earth in distant orbits. (Image credit: Getty)

The difference that low earth orbit makes in an astronaut's life span may be negligible — better suited for jokes among siblings than actual life extension or visiting the distant future — but the dilation in time between people on Earth and GPS satellites flying through space does make a difference. The [Global Positioning System](#), or GPS, helps us know exactly where we are by communicating with a network of a few dozen satellites positioned in a high Earth orbit. The satellites circle the planet from 12,500 miles (20,100 kilometers) away, moving at 8,700 mph (14,000 km/h).

According to special relativity, the faster an object moves relative to another object, the slower that first object experiences time. For GPS satellites with atomic clocks, this effect cuts 7 microseconds, or 7 millionths of a second, off each day, according to the American Physical Society publication [Physics Central](#).

Then, according to general relativity, clocks closer to the center of a large gravitational mass like Earth tick more slowly than those farther away. So, because the GPS satellites are much farther from the center of Earth compared to clocks on the surface, Physics Central added, that adds another 45 microseconds onto the GPS satellite clocks each day. Combined with the negative 7 microseconds from the special relativity calculation, the net result is an added 38 microseconds.

This means that in order to maintain the accuracy needed to pinpoint your car or phone — or, since the system is run by the U.S. Department of Defense, a military drone — engineers must account for an extra 38 microseconds in each satellite's day. The atomic clocks onboard don't tick over to the next day until they have run 38 microseconds longer than comparable clocks on Earth.

Given those numbers, it would take more than seven years for the atomic clock in a GPS satellite to un-sync itself from an Earth clock by more than a blink of an eye. (We did the math: If you estimate a blink to last at least 100,000 microseconds, as the Harvard [Database of Useful Biological Numbers](#) does, it would take thousands of days for those 38 microsecond shifts to add up.)

This kind of time travel may seem as negligible as the Kelly brothers' age gap, but given the hyper-accuracy of modern GPS technology, it actually does matter. If it can communicate with the satellites whizzing overhead, your phone can nail down your location in space and time with incredible accuracy.

CAN WORMHOLES TAKE US BACK IN TIME?

General relativity might also provide scenarios that could allow travelers to go back in time, [according to NASA](#). But the physical reality of those time-travel methods is no piece of cake.

[Wormholes](#) are theoretical "tunnels" through the fabric of space-time that could connect different moments or locations in reality to others. Also known as Einstein-Rosen bridges

or white holes, as opposed to black holes, speculation about wormholes abounds. But despite taking up a lot of space (or space-time) in science fiction, no wormholes of any kind have been identified in real life.

"The whole thing is very hypothetical at this point," Stephen Hsu, a professor of theoretical physics at the University of Oregon, [told Space.com sister site Live Science](#). "No one thinks we're going to find a wormhole anytime soon."

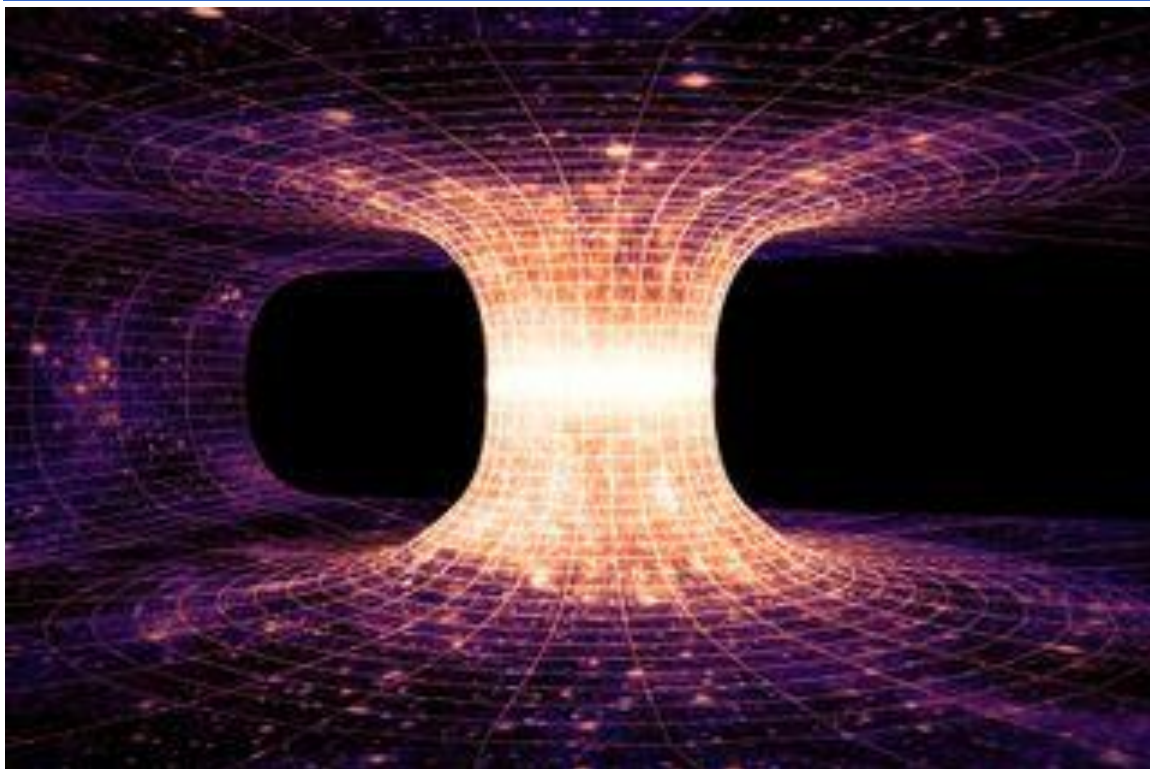
Primordial wormholes are predicted to be just 10^{-34} inches (10^{-33} centimeters) at the tunnel's "mouth". Previously, they were expected to be too unstable for anything to be able to travel through them. However, a study claims that this is not the case, [Live Science reported](#).

The theory, which suggests that wormholes could work as viable space-time shortcuts, was described by physicist Pascal Koiran. As part of the study, Koiran used the Eddington-Finkelstein metric, as opposed to the Schwarzschild metric which has been used in the majority of previous analyses.

In the past, the path of a particle could not be traced through a hypothetical wormhole. However, using the Eddington-Finkelstein metric, the physicist was able to achieve just that.

Koiran's paper was described in October 2021, in the preprint database [arXiv](#), before being published in the Journal of Modern Physics D.

ALTERNATE TIME TRAVEL THEORIES



While Einstein's theories appear to make time travel difficult, some researchers have proposed other solutions that could allow jumps back and forth in time. These alternate theories share one major flaw: As far as scientists can tell, there's no way a person could survive the kind of gravitational pulling and pushing that each solution requires.

Infinite cylinder theory

Astronomer Frank Tipler proposed a mechanism (sometimes known as a [Tipler Cylinder](#)) where one could take matter that is 10 times the sun's mass, then roll it into a very long, but very dense cylinder. [The Anderson Institute](#), a time travel research organization, described the cylinder as "a black hole that has passed through a spaghetti factory." After spinning this black hole spaghetti a few billion revolutions per minute, a spaceship nearby — following a very precise spiral around the cylinder — could travel backward in time on a "closed, time-like curve," according to the Anderson Institute.

The major problem is that in order for the Tipler Cylinder to become reality, the cylinder would need to be infinitely long or be made of some unknown kind of matter. At least for the foreseeable future, endless interstellar pasta is beyond our reach.

Time donuts

Theoretical physicist Amos Ori at the Technion-Israel Institute of Technology in Haifa, Israel, proposed a model for a time machine made out of curved space-time — a donut-shaped vacuum surrounded by a sphere of normal matter.

"The machine is space-time itself," Ori [told Live Science](#). "If we were to create an area with a warp like this in space that would enable time lines to close on themselves, it might enable future generations to return to visit our time."

Amos Ori

Theoretical physicist

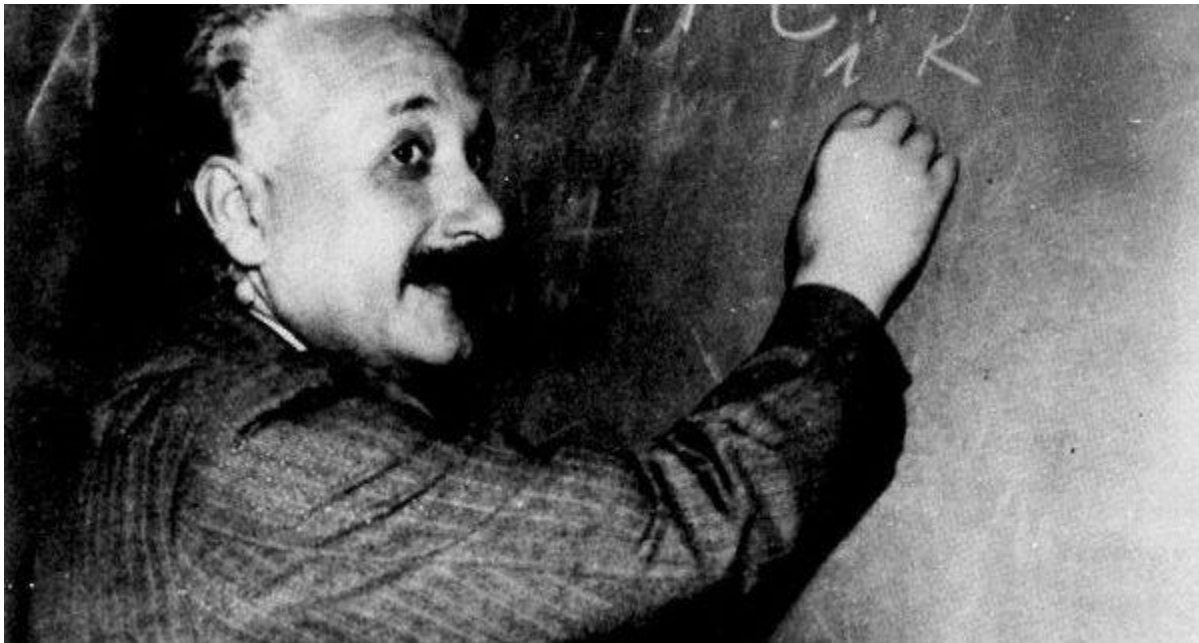
Amos Ori is a theoretical physicist at the Technion-Israel Institute of Technology in Haifa, Israel. His research interests and publications span the fields of general relativity, black holes, gravitational waves and closed time lines.

There are a few caveats to Ori's time machine. First, visitors to the past wouldn't be able to travel to times earlier than the invention and construction of the time donut. Second, and more importantly, the invention and construction of this machine would depend on our ability to manipulate gravitational fields at will — a feat that may be theoretically possible but is certainly beyond our immediate reach.

How do 'moving rulers shrink'? The strange physics behind special relativity

published May 20, 2024

Special relativity is beyond weird. Among its many statements are that moving clocks run slow and that moving rulers shrink. But how are we supposed to make sense of this?



Albert Einstein at the blackboard. (Image credit: NASA)

Special relativity is beyond weird. Among its many statements are that moving clocks run slow and that moving rulers shrink. But how are we supposed to make sense of this? To understand the physics of relativity, we have to dip back in [time](#) a bit.

In 1865, [James Clerk Maxwell](#) discovered that what we call "light" is really waves of [electricity and magnetism](#). But like all waves, these waves needed to wave through something. Sound waves move through air. Ocean waves move through oceans. So Maxwell believed light waves traveled through a substance known today as the appropriately old-timey "luminiferous aether."

This "aether" (or "ether") had to have some strange properties. You couldn't feel it, touch it, smell it or otherwise sense it. So it had to be nearly invisible but also had to allow light to wave through it, so it had to exist. In the late 1800s, there were many debates about the nature of the aether, and it turns out, everybody was wrong.

But they didn't know they were wrong until a pair of scientists decided to measure our movement through the aether in 1887. That pair was Albert Michelson, of the Case School of Applied Science, and Edward Morley, of Western Reserve University, who devised an

experiment we now call the Michelson-Morley experiment at a place we now call Case Western Reserve University.

The basic idea is that if the aether exists, we should be swimming through it and we should notice this movement as a change in the [speed of light](#).

The Michelson-Morley experiment tried to measure this and totally failed. So there was a problem. Light is a wave, and it must move through something — the aether. But we can't seem to measure our own motion through the aether. So what's going on?

Lengthy contractions

Shortly after the Michelson-Morley experiment, physicist Oliver Heaviside noticed something funky: When electric charges are set in motion, their electric fields squish a little bit along the direction of that motion.

Then came Hendrik Lorentz, who had an absolutely wonderful thought: If we're all made of electric charges and the fields shrink when they move, then maybe *we* shrink when we move. So we can't measure changes in the speed of light because of length contraction — as we move through the aether, the speed of light changes, but so does our measurement apparatus, thus canceling it out.

This was considered a rather successful theory; it worked and explained all of the data. Matter squishes when it moves from some physical interactions, and the aether is there but undetectable.

Then, [Einstein](#) showed up and asked a very important question: If this aether is always and forever undetectable, then why do we need it? Why don't we just let things contract on their own — not to explain away some experimental result we don't like, but as a bare fact of [the universe](#)?

This is Einstein's big result. Other people were working in the direction of relativity, but nobody made the leap he did. Einstein declared length contraction to be a feature, not a bug, in the universe. No more aether, no more attempts to fit a square electromagnetic peg into a round aether hole. Lengths contract when they move. Period. End of discussion.

Einstein's length contraction was a little different from Lorentz's. For Lorentz, it was a physical effect, stuff smooshing together. For Einstein, it was a feature of [space](#) itself, independent of the actual objects. And this realization allowed Einstein to take yet another powerful leap.

The birth of relativity

To make it all work, Einstein realized there had to be some give-and-take. You can't just have length contraction — moving rulers shrink — on its own. You also need time dilation — moving clocks run slow. These always work together to allow all observations and all perspectives to make sense.

For example, take the humble muon, the heavier sibling of the [electron](#). Because the muon is massive, it has a short life span — only 2.2 microseconds. When energetic particles strike

air molecules in the upper atmosphere, they generate muons that then come streaking down toward the ground.

These muons travel at nearly the speed of light, but that's still not fast enough for them to reach the ground during their short lives. But relativity teaches us that moving clocks run slow — from our perspective, the muons persist much longer, so they have more than enough time to make the journey.

But the muon has a different perspective. It doesn't experience time dilation from its point of view, from which it will exist for only 2.2 microseconds. So how does the muon have enough time to reach the ground from its perspective? The answer on this side is length contraction — from the perspective of the speedy muon, the distance to the ground is much shorter, so it doesn't have that far to go.

[Special relativity](#) is the mathematical machinery we need to switch perspectives and keep everything organized. The universe may be crazy, but at least it follows rules we can understand.

Distortions in space-time could put Einstein's theory of relativity to the ultimate test

published July 3, 2023

Observing time distortions could show whether Einstein's theory of general relativity accounts for the mysteries of dark matter and dark energy.

Gravitational lensing -- a phenomenon predicted by Albert Einstein's theory of relativity --

Scientists could soon test Einstein's theory of [general relativity](#) by measuring the distortion of time.

According to new research published June 22 in the journal [Nature Astronomy](#), the newly proposed method turns the edge of space and time into a vast cosmic lab to investigate if general relativity can account for [dark matter](#) — a mysterious, invisible form of matter that can only be inferred by its gravitational influence on the universe's visible matter and energy — as well as the accelerating expansion of the universe due to [dark energy](#). The method is ready to be tested on future surveys of the deep universe, according to the study authors.

General relativity states that gravity is the result of mass warping the fabric of space and time, which Einstein lumped into a four-dimensional entity called [space-time](#). According to relativity, time passes more slowly close to a massive object than it does in a mass-less vacuum. This change in the passing of time is called time distortion.

Since its introduction in 1915, general relativity has been tested extensively and has become our [best description of gravity on tremendous scales](#). But scientists aren't yet sure if it can explain invisible dark matter and dark energy, which together account for around 95% of the energy and matter in the universe.

"Time distortion predicted by general relativity has already been measured very precisely at small distances," [Camille Bonvin](#), lead study author and an associate professor at the University of Geneva, told Live Science via email. "It has been measured for planes flying around the Earth, for stars in our galaxy, and also for clusters of galaxies. We propose a method to measure the distortion of time at very large distances."

The method suggests testing time distortion by measuring redshift, the change in the frequency of light an object emits as it moves away from us. Bonvin said the difference here is that this technique measures redshift caused as light attempts to climb out of a gravitational well, a "dent" in space-time created by a massive object.

"This climb changes the frequency of the light because time passes at different rates inside and outside of the gravitational well," she said. "As a consequence, the color of the light is changed; it is shifted to red. ... By measuring gravitational redshift, we obtain a measurement of the distortion of time."

Time to test general relativity

Time distortion suggests that time is not absolute in our universe but rather passes at varying rates depending on gravitational fields. This idea is not exclusive to general relativity.

"Time distortion exists in all modern theories of gravity," Bonvin said. "However, the amplitude of the time distortion — how much the presence of a massive object slows down time — varies from theory to theory."

In general relativity, the distortions of time and space are predicted to be the same; in other theories of gravity, this is not always the case. That means that by measuring the distortion of time and comparing it to the distortion of space, physicists can test the validity of general relativity.

The team's new method could also test another leading theory of the cosmos: Euler's formula, which astronomers use to calculate the movement of galaxies. Specifically, the team's proposed measurement of time distortion could prove whether dark matter obeys [Euler's equation](#), as prior studies of time distortion have presumed.

The team's method could be employed by future missions, including the European Space Agency's Euclid telescope, which is set to launch in July, and the Dark Energy Spectroscopic Instrument, which is three years into its five-year survey of the universe.

"It will be possible to measure the distortion of time with the data delivered by these surveys," Bonvin said. "This is very interesting because, for the first time, we will be able to compare the distortion of time with that of space, to test if general relativity is valid, and we will also be able to compare the distortion of time with the velocity of galaxies, to see if Euler's equation is valid. With one new measurement, we will be able to test two fundamental laws."

Was Einstein wrong? The case against space-time theory

published February 28, 2022

If Einstein was wrong, could killing off space-time theory help us better understand the universe?

Was Einstein wrong? Do we have to kill off the theory of space and time to make sense of the universe?



As in history, revolutions are the lifeblood of science. Bubbling undercurrents of disquiet boil over until a new regime emerges to seize power. Then everyone's attention turns to toppling their new ruler. The king is dead, long live the king.

This has happened many times in the history of physics and astronomy. First, we thought [Earth](#) was at the center of the [solar system](#) — an idea that stood for over 1,000 years. Then [Nicolaus Copernicus](#) stuck his neck out to say that the whole system would be a lot simpler if we are just another planet orbiting the [sun](#). Despite much initial opposition, the old [geocentric](#) picture eventually buckled under the weight of evidence from the newly invented telescope.

Then [Isaac Newton](#) came along to explain that gravity is why the planets [orbit the sun](#). He said all objects with mass have a gravitational attraction towards each other. According to his ideas we orbit the sun because it is pulling on us, the [moon](#) orbits Earth because we are pulling on it. Newton ruled for two-and-a-half centuries before [Albert Einstein](#) turned up in 1915 to usurp him with his [General Theory of Relativity](#). This new picture neatly explained

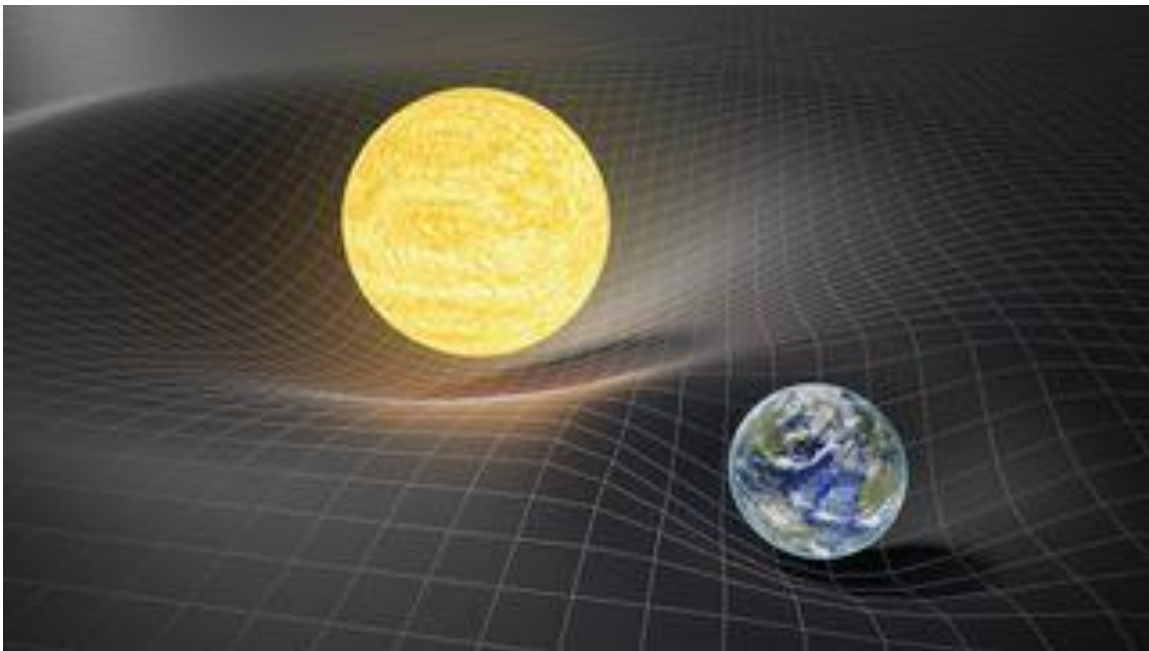
inconsistencies in [Mercury](#)'s orbit, and was famously confirmed by observations of a [solar eclipse](#) off the coast of Africa in 1919.(Image credit: Future)

This article is brought to you by [All About Space](#).

[All About Space](#) magazine takes you on an awe-inspiring journey through our solar system and beyond, from the amazing technology and spacecraft that enables humanity to venture into orbit, to the complexities of space science.

Instead of a pull, Einstein saw gravity as the result of curved space. He said that all objects in the universe sit in a smooth, four-dimensional fabric called space-time. Massive objects such as the sun warp the space-time around them, and so Earth's orbit is simply the result of our planet following this curvature. To us that looks like a Newtonian gravitational pull. This space-time picture has now been on the throne for over 100 years, and has so far vanquished all pretenders to its crown. The discovery of [gravitational waves](#) in 2015 was a decisive victory, but, like its predecessors, it too might be about to fall. That's because it is fundamentally incompatible with the other big beast in the physics zoo: Quantum theory.

THE STRANGE QUANTUM WORLD



Massive bodies warp the fabric of space and time around them, leading to nearby objects following a curved path. (Image credit: vchal via Getty Images)

The [quantum world](#) is notoriously weird. Single particles can be in two places at once, for example. Only by making an observation do we force it to 'choose'. Before an observation we can only assign probabilities to the likely outcomes. In the 1930s, Erwin Schrödinger devised a famous way to expose how perverse this idea is. He imagined a cat in a sealed box accompanied by a vial of poison attached to a hammer. The hammer is hooked up to a device that measures the quantum state of a particle. Whether or not the hammer smashes

the vial and kills the cat hinges on that measurement, but quantum physics says that until such a measurement is made, the particle is simultaneously in both states, which means the vial is both broken and unbroken and the cat is alive and dead.

Such a picture cannot be reconciled with a smooth, continuous fabric of space-time. "A gravitational field cannot be in two places at once," said Sabine Hossenfelder, a theoretical physicist at the [Frankfurt Institute for Advanced Studies](#). According to Einstein, space-time is warped by matter and energy, but quantum physics says matter and energy exist in multiple states simultaneously — they can be both here and over there. "So where is the gravitational field?" asks Hossenfelder. "Nobody has an answer to that question. It's kind of embarrassing," she said.

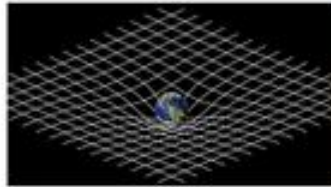
THEORIES THAT DON'T PLAY NICELY



One way to reconcile general relativity and quantum theory says reality is made of vibrating strings. (Image credit: koto_feja via Getty Images)

Try and use general relativity and quantum theory together, and it doesn't work. "Above a certain energy, you get probabilities that are larger than one," said Hossenfelder. One is the highest probability possible — it means an outcome is certain. You can't be more certain than certain. Equally, calculations sometimes give you the answer infinity, which has no real physical meaning. The two theories are therefore mathematically inconsistent. So, like many monarchs throughout history, physicists are seeking a marriage between rival factions to secure peace. They're searching for a theory of [quantum gravity](#) — the ultimate diplomatic exercise in getting these two rivals to share the throne. This has seen theorists turn to some outlandish possibilities.

SPACE-TIME THEORY TIMELINE



NASA

1915: EINSTEIN PUBLISHES GENERAL THEORY OF RELATIVITY

The famous physicist suggests gravity is not a Newtonian force of attraction, but rather the result of curved spacetime. The Earth, for example, follows the local shape of spacetime created by the presence of the sun.



1919: Landessternwarte Heidelberg-Königstuhl, H. Gysin, A. S. Eddington, & C. Davidson

1939: BLACK HOLES PREDICTED:

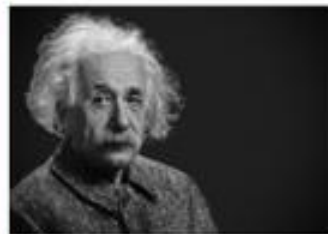
Robert Oppenheimer — the father of the atomic bomb — writes a paper suggesting that a collapsing star would create a well in spacetime so deep that even light could not escape the distortion. John Wheeler would later call such objects "black holes".



B. Mark L. Cattech, JPL

1908: MINKOWSKI COINS THE PHRASE

Einstein's old mathematics professor Hermann Minkowski coins the phrase spacetime as the entity that both space and time are a part of. He once called Einstein "a lazy dog who never bothered about mathematics at all."



Portrait

1919: EDDINGTON'S ECLIPSE VINDICATES EINSTEIN

Both Newton's and Einstein's interpretation of gravity predicts that the Sun will bend distant starlight around it, causing the star to appear temporarily displaced from its usual position. Crucially they disagreed on the size of this displacement. Eddington looked at the position of stars close to the sun during a solar eclipse and his findings confirmed Einstein's view as correct.



NASA's Goddard Space Flight Center/Jeremy Schnittman

2015: GRAVITATIONAL WAVES DISCOVERED

Einstein predicted that objects moving through the fabric of spacetime would create ripples, just as objects do when moving through water. Yet it took a century to see them. In 2015 the LIGO gravitational wave detector saw ancient ripples from two colliding black holes. It was another landmark vindication of general relativity and spacetime.

(Image credit: Future. Images from various sources (credited below each image).)

Arguably the most famous is [string theory](#). It's the idea that sub-atomic particles such as electrons and quarks are made from tiny vibrating strings. Just as you can play strings on a musical instrument to create different notes, string theorists argue that different combinations of strings create different particles. The attraction of the theory is that it can reconcile general relativity and quantum physics, at least on paper. However, to pull that particular rabbit out of the hat, the strings have to vibrate across eleven dimensions — seven more than the four in Einstein's space-time fabric. As yet there is no experimental evidence that these extra dimensions really exist. "It might be interesting mathematics, but whether it describes the space-time in which we live, we don't really know until there is an experiment," said Jorma Louko from the University of Nottingham.

Partly inspired by string theory's perceived failings, other physicists have turned to an alternative called Loop Quantum Gravity (LQG). They can get the two theories to play nicely if they do away with one of the central tenets of general relativity: That space-time is a smooth, continuous fabric. Instead, they argue, space-time is made up of a series of interwoven loops — that it has structure at the smallest size scales. This is a bit like a length of cloth. At first glance it looks like one smooth fabric. Look closely, however, and you'll see it is really made of a network of stitches. Alternatively, think of it like a photograph on a computer screen: Zoom in, and you'll see it is really made of individual pixels.

The trouble is that when LQG physicists say small, they mean really small. These defects in space-time would only be apparent on the level of the Planck scale — around a trillionth of a trillionth of a meter. That's so tiny that there would be more loops in a cubic centimeter of space than cubic centimeters in the entire observable universe. "If space-time only differs on the Planck scale then this would be difficult to test in any particle accelerator," says Louko. You'd need an atom smasher a 1,000-trillion-times more powerful than the Large Hadron Collider (LHC) at CERN. One about as big as our entire [Milky Way galaxy](#).

However, a team of physicists from the UK, France and Hong Kong may soon have another way to test out this idea. They hope to use an ultra-cold gas of several billion caesium atoms existing in a state known as a Bose-Einstein condensate to see if gravity is really quantum after all.

In the meantime, the universe itself provides another way to look for tiny spacetime defects.

THE ULTIMATE COSMIC TEST

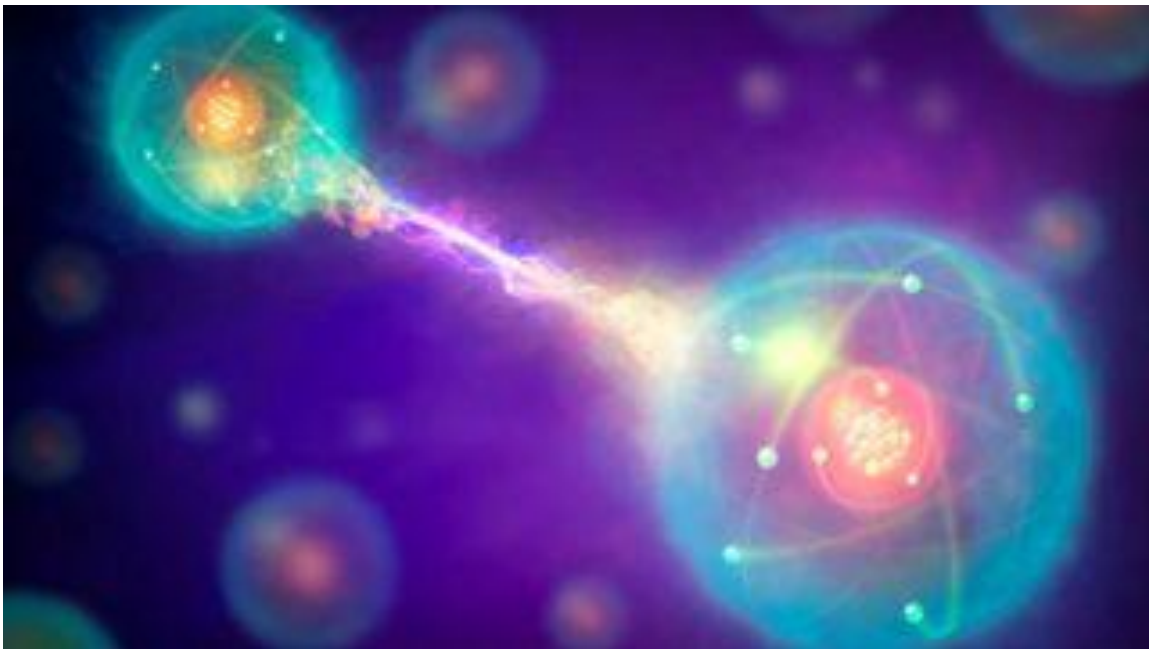
Light arriving here from the furthest reaches of the universe has traveled through billions of [light-years](#) of space-time along the way. While the effect of each space-time defect would be tiny, over those distances interactions with multiple defects might well add up to a potentially observable effect. For the last decade, astronomers have been using light from far-off [Gamma Ray Bursts](#) to look for evidence in support of LQG. These cosmic flashes are

the result of massive stars collapsing at the ends of their lives, and there is something about these distant detonations we currently cannot explain. "Their spectrum has a systematic distortion to it," said Hossenfelder, but no one knows if that is something that happens on the way here or if it's something to do with the source of the bursts themselves. The jury is still out.

To make progress, we might have to go a step further than saying space-time isn't the smooth, continuous fabric Einstein suggested. According to Einstein, space-time is like a stage that remains in place whether actors are treading its boards or not —even if there were no stars or planets dancing around, space-time would still be there. However, physicists Laurent Freidel, Robert Leigh, and Djordje Minic think that this picture is holding us back. They believe space-time doesn't exist independently of the objects in it. Space-time is defined by the way objects interact. That would make space-time an artifact of the quantum world itself, not something to be combined with it. "It may sound kooky," said Minic, "but it is a very precise way of approaching the problem."

The attraction of this theory — called modular space-time — is that it might help solve another long-standing problem in theoretical physics regarding something called locality, and a notorious phenomenon in quantum physics called entanglement. Physicists can set up a situation whereby they bring two particles together and link their quantum properties. They then separate them by a large distance and find they are still linked. Change the properties of one and the other will change instantly, as if information has traveled from one to the other faster than the speed of light in direct violation of relativity. Einstein was so perturbed by this phenomenon that he called it 'spooky action at a distance'.

SEPARATION ANXIETY



Quantum entanglement is when two particles link together in a certain way no matter how far apart they are in space. Their state remains the same. (Image credit: MARK GARLICK/SCIENCE PHOTO LIBRARY via Getty Images.)

Modular space-time theory can accommodate such behavior by redefining what it means to be separated. If space-time emerges from the quantum world, then being closer in a quantum sense is more fundamental than being close in a physical sense. "Different observers would have different notions of locality," said Minic, "it depends on the context." It's a bit like our relationships with other people. We can feel closer to a loved one far away than the stranger who lives down the street. "You can have these non-local connections as long as they are fairly small," said Hossenfelder.

Freidel, Leigh, and Minic have been working on their idea for the last five years, and they believe they are slowly making progress. "We want to be conservative and take things step-by-step," said Minic, "but it is tantalizing and exciting". It's certainly a novel approach, one that looks to "gravitationalize" the quantum world rather than quantizing gravity as in LQG. Yet as with any scientific theory, it needs to be tested. At the moment the trio are working on how to fit time into their model.

This may all sound incredibly esoteric, something only academics should care about, but it could have a more profound effect on our everyday lives. "We sit in space, we travel through time, and if something changes in our understanding of space-time this will impact not only on our understanding of gravity, but of quantum theory in general," said Hossenfelder. "All our present devices only work because of quantum theory. If we understand the quantum structure of space-time better that will have an impact on future technologies — maybe not in 50 or 100 years, but maybe in 200," she said.

The current monarch is getting long in tooth, and a new pretender is long overdue, but we can't decide which of the many options is the most likely to succeed. When we do, the resulting revolution could bear fruit not just for theoretical physics, but for all.

The 'twin paradox' shows us what it really means for time to be relative



How do we make sense of a world in which time is relative? (Image credit: Billy Currie Photography via Getty Images)

Einstein's theory of special relativity teaches us that time is relative. But what does it mean for time to be relative? How can we live in a universe where nobody can agree on when events start, when they end and how long they last? The infamous "twin paradox" showcases what living in a truly relativistic world is like.

Put simply, [special relativity](#) tells us that moving clocks run slowly. This is a phenomenon called time dilation, and it's a cold, hard fact of the universe. [Einstein](#) had to introduce the concept to rescue something he thought was much more fundamental: the universality of physical laws. If we want the laws of physics — which also means the experience of physics — to be the same regardless of your reference frame, perspectives have to shift for observers at different speeds.

Special relativity says that a clock attached to a moving object will tick at a slower rate than one standing still. And what goes for moving clocks goes for everything else; physics, chemistry and biology all operate at a slower pace in moving frames of reference.

It's very difficult to measure this effect at human scales, because it only shows up to a significant degree as one approaches the [speed of light](#). Still, it's measurable. In 1971, physicists Joseph Hafele and Richard Keating put atomic clocks onboard jet aircraft and sent them flying around the world. When the clocks returned, they were out of sync with a ground-based clock by exactly the amount predicted by special relativity.

To explore the full implications of this idea, let's start with some hypothetical twins, Alice and Bob. As long as they remain near each other, their clocks will stay synchronized and they will age at the same rate. But if Bob were to get in a rocket ship and cruise around the [galaxy](#) at near light speed, things would be a bit different.

For Bob, maybe only a few months or a couple of years passed on his journey. But depending on how fast he went, it could have been decades, or even centuries, for Alice.

The actual paradox

As head-scratching as this tale is, it's not a paradox. This is exactly what the physics of special relativity demands: Different observers in the universe will have different calculations of the flow of time depending on their velocity.

So here's the *actual* paradox. Nothing feels different for Bob when he's traveling. It's not like he moves in slow motion or anything. Everything just feels totally normal — so normal, in fact, that as long as he's not accelerating, he can't even tell he's moving at all.

This is the crucial thought experiment that helped Einstein develop special relativity. If you're moving at the exact same speed (no accelerations or decelerations), it's impossible to tell if you're the one who's moving, or if you're staying still and the rest of the universe is moving. Have you ever been in a car and you see the car next to you reverse, and for a moment, you think you're moving forward? Your mind is relying on outside cues to help tell you if you're in motion.

So, from Bob's perspective, he's staying perfectly still, and it's Alice (and the whole [Earth](#)) that's racing away from him. Yes, it sounds improbable, but from the point of view of physics, Bob can't tell the difference. In Bob's calculations, his clock is running normally, and it's Alice's that should be running slowly. So, when they meet again, she should be younger than him, because not as much time has passed for her.

But Alice says the exact same thing about Bob, because according to her, she's the one staying still and he's the one moving.

Who's correct, Alice or Bob? This is the real paradox.

A certain point of view

We can solve the twin paradox by looking at the whole picture. It's true that as long as Bob is flying along at a constant speed, he and Alice will fundamentally disagree about the flow of time, and both perspectives will be valid. But for them to compare notes, Bob has to return to Earth. In other words, he needs to slow down, stop, turn his ship around, reaccelerate and come back home.

This act of turning around has a major impact on Bob's reckoning of time. He will be doing something that shifts him away from his special frame of reference. And he'll be able to tell he's doing it not by looking at the outside universe but by making observations while inside

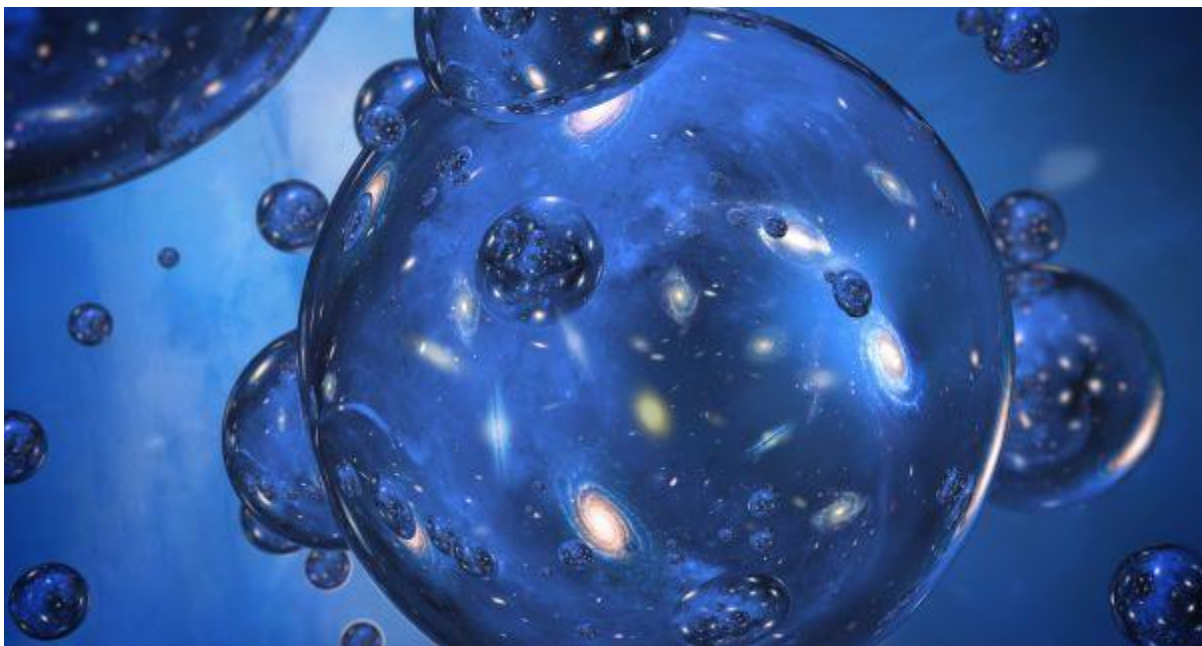
his rocket — for example, the vibrations of the engines and the push of his body against the floor during deceleration.

Because of this asymmetry, Bob's perspective is no longer as valid as Alice's, and he can no longer claim that he is standing still while the universe is moving around him. When he finally makes it back to Earth, he will know that he was the traveling twin and that he was the one moving at close to the speed of light.

The mathematics of special relativity tells us how much Alice and Bob will age in their own frames of reference, and that same math demonstrates that they will end up agreeing on the numbers in the end.

Our universe may have a twin that runs backward in time

An anti-universe running backwards in time could explain dark matter and cosmic inflation.



If the universe has a twin and on that twin time runs backward, then scientists could explain dark matter. (Image credit: MARK GARLICK/SCIENCE PHOTO LIBRARY/Getty Images)

A wild new theory suggests there may be another "anti-universe," running backward in time prior to the Big Bang.

The idea assumes that the early universe was small, hot and dense — and so uniform that time looks symmetric going backward and forward.

If true, the new [theory](#) means that [dark matter](#) isn't so mysterious; it's just a new flavor of a ghostly particle called a [neutrino](#) that can only exist in this kind of universe. And the theory implies there would be no need for a period of "inflation" that rapidly expanded the size of the young cosmos soon after the [Big Bang](#). If true, then future experiments to hunt for gravitational waves, or to pin down the mass of neutrinos, could answer once and for all whether this mirror anti-universe exists.

Preserving symmetry

Physicists have identified a set of fundamental symmetries in nature. The three most important symmetries are: charge (if you flip the charges of all the particles involved in an interaction to their opposite charge, you'll get the same interaction); parity (if you look at the mirror image of an interaction, you get the same result); and time (if you run an interaction backward in time, it looks the same).

Physical interactions obey most of these symmetries most of the time, which means that there are sometimes violations. But physicists have never observed a violation of a combination of all three symmetries at the same time. If you take every single interaction observed in nature and flip the charges, take the mirror image, and run it backward in time, those interactions behave exactly the same.

This fundamental symmetry is given a name: CPT symmetry, for charge (C), parity (P) and time (T).

In a [new paper](#) recently accepted for publication in the journal *Annals of Physics*, scientists propose extending this combined symmetry. Usually this symmetry only applies to interactions — the forces and fields that make up the physics of the cosmos. But perhaps, if this is such an incredibly important symmetry, it applies to the whole entire universe itself. In other words, this idea extends this symmetry from applying to just the "actors" of the universe (forces and fields) to the "stage" itself, the entire physical object of the universe.

Creating dark matter

We live in an expanding universe. This universe is filled with lots of particles doing lots of interesting things, and the evolution of the universe moves forward in time. If we extend the concept of CPT symmetry to our entire cosmos, then our view of the universe can't be the entire picture.

Instead, there must be more. To preserve the CPT symmetry throughout the cosmos, there must be a mirror-image cosmos that balances out our own. This cosmos would have all

opposite charges than we have, be flipped in the mirror, and run backward in time. Our universe is just one of a twin. Taken together, the two universes obey CPT symmetry.

The study researchers next asked what the consequences of such a universe would be.

They found many wonderful things.

For one, a CPT-respecting universe naturally expands and fills itself with particles, without the need for a long-theorized period of rapid expansion known as inflation. While there's a lot of evidence that an event like inflation occurred, the theoretical picture of that event is incredibly fuzzy. It's so fuzzy that there is plenty of room for proposals of viable alternatives.

Second, a CPT-respecting universe would add some additional neutrinos to the mix. There are three known neutrino flavors: the electron-neutrino, muon-neutrino and tau-neutrino. Strangely, all three of these neutrino flavors are left-handed (referring to the direction of its spin relative to its motion). All other particles known to physics have both left- and right-handed varieties, so physicists have long wondered if there are additional right-handed neutrinos.

A CPT-respecting universe would demand the existence of at least one right-handed neutrino species. This species would be largely invisible to physics experiments, only ever influencing the rest of the universe through gravity.

But an invisible particle that floods the universe and only interacts via gravity sounds a lot like dark matter.

The researchers found that the conditions imposed by obeying CPT symmetry would fill our universe with right-handed neutrinos, enough to account for the dark matter.

Predictions in the mirror

We would never have access to our twin, the CPT-mirror universe, because it exists "behind" our Big Bang, before the beginning of our cosmos. But that doesn't mean we can't test this idea.

The researchers found a few observational consequences of this idea. For one, they predict that the three known left-handed neutrino species should all be Majorana particles, which means that they are their own antiparticles (in contrast to normal particles like the [electron](#), which have antimatter counterparts called the positrons). As of now, physicists aren't sure if neutrinos have this property or not. Additionally, they predict that one of the neutrino species should be massless. Currently, physicists can only place upper limits on the neutrino masses. If physicists can ever conclusively measure the neutrino masses, and one of them is indeed massless, that would greatly bolster the idea of a CPT-symmetric universe.

Lastly, in this model the event of inflation never occurred. Instead, the universe filled with particles naturally on its own. Physicists believe that inflation shook space-time to such a tremendous degree that it flooded the cosmos with gravitational waves. Many experiments are on the hunt for these primordial gravitational waves. But in a CPT-symmetric universe, no such waves should exist. So if those searches for primordial gravitational waves turn up empty, that might be a clue that this CPT-mirror universe model is correct.

“UFO’s and the New Physics” by Kim Burrafato in conversation with Jack Sarfatti, Ph.D.

This very interesting 1995 article was found on archive.org. The old HTML formatting confuses modern browsers, making the original unreadable, so I’ve placed it here for easier reading:

UFO’s and the New Physics

UFOs are a controversial and compelling enigma. We remain uncertain of what these objects are, or whether they even exist. Conventional wisdom is that most UFOs are likely erroneous observations, along with a bit of mass hysteria and some outright charlatanism. Was there really a UFO crash at Roswell in 1947? But what if we were to assume — purely as an exercise — that UFOs are actually products of a starfaring civilization?

The rational mind rebels at the idea. UFOs allegedly exhibit outlandish behavior. Witnesses report incredible things like instant accelerations, right angle turns at enormous velocities, and instant stops. These objects are also reported to change their shapes and colors, and simply disappear like phantoms instantly leaping from one universe to

another. UFOs violate the laws of physics. No terrestrial spacecraft are capable of such magical feats of reality engineering.

It's no wonder that most scientists consider the subject of UFOs patently absurd and not worthy of serious discussion. Can modern physics ever hope explain the UFO phenomenon to fit within the current world view? Or is an entirely new physics required? This article will address the question "If UFOs are real, then how do they work?"

Clear Intent, by [Larry Fawcett and Barry Greenwood](#), presents evidence of Air Force observations of these phenomena. Included in the book were published Department of Defense documents, released under the Freedom of Information Act, that report repeated UFO penetrations of high security ICBM bases and nuclear weapons storage areas back in the 1970s. One major mission of the American intelligence community is to anticipate technology that might disrupt our defense systems. Judging from the documents Fawcett and Greenwood published, the Department of Defense and Air Force are not on top of the situation, with regard to UFOs buzzing some of our most sensitive defense areas.

Recent newspaper and magazine articles have also reported that the Air Force is testing some new kind of "black project" aircraft, code named "Aurora." According to the news accounts, this ultra-secret, high altitude hypersonic aircraft creates powerful vertical, earthquake-

like jolts, felt by thousands of Southern California residents, as it passes high overhead at over four thousand miles per hour.

Anything that burns a propellant in a reaction chamber, and then directs the exhaust products of that reaction out of a nozzle can be described as a rocket. Aurora's propulsion system is obviously rocket-like. It makes a lot of noise. It follows, then, that any rocket capable of the tremendous speed and maneuvering attributed to UFOs would be impossible *not* to notice.

But the majority of UFO witnesses report hearing nothing like the continuous, low frequency rumbling sounds that would normally accompany fuel combustion propulsion based rockets; nor do they report seeing the kind of exhaust products one would expect to see with rockets. If not reporting objects that seem to be entirely silent, some witnesses have reported hearing loud, but brief bang-like sounds as UFOs take off, as well as both low and high frequency humming sounds.

We're forced to conclude, then, that UFOs don't operate on terrestrial rocket science principles. In a single stroke, we can eliminate not only all present solid and chemical fuel based rockets, but even future exotic propulsion schemes like nuclear-electric ion rockets, interstellar hydrogen fusion ramjets, and that favorite of science fiction writers and scientists alike, antimatter-matter annihilation rockets, as viable candidates for possible UFO propulsion.

The major problem with applying conventional rocket science to [interstellar travel](#) is the *Einstein barrier*: the exhaust speed of the propellant relative to a rocket is limited to three hundred thousand kilometers per second, the speed of light in a vacuum. At present, this barrier prevents practical interstellar travel because a physically unreasonable quantity of conventional fuel is required to get reasonably close to the speed of light in a rocket. Any starship built on proven or even highly speculative principles of rocket propulsion, such as the very efficient anti-matter drive popularized in Star Trek, would still need to generate much more energy than is generated on Earth every year. The manufacturing costs would be many times the gross national products of America, all of Europe and Japan combined. So, we're faced with both a physical and an economic absurdity. The starship Enterprise still remains a playful notion at best.

Cheap and practical interstellar flight is possible only if Einstein's barrier can be overcome. If UFOs are indeed from other star systems, then they have obviously broken that barrier.

Like conventional rockets and jets, UFOs seem to generate their own internal propulsion. As far as we can tell, they are not pushed along by an external energy source, like a laser or particle beam, or the solar wind. They evidently operate on distinctly "alien" propulsion principles than those we're accustomed to. Could we ever expect to understand such principles?

Theoretical subtleties inherent within Einstein's general theory of relativity (gravity) and quantum mechanics may hold the answer. If it is possible to physically alter or deform four-dimensional space-time, then a kind of space-time tunnel, or time travel gate, can be constructed. In current physics, such theoretical tunnels are known as traversable wormholes.

Cal Tech physicists Kip Thorne and Michael Morris, along with Igor Novikov of Moscow State University and others, have published a number of papers in the prestigious *Physical Review* on the physics of time travel and traversable wormholes. A traversable wormhole is literally a shortcut through both space and time.

An advanced extraterrestrial civilization , capable of cosmic-scale engineering, could conceivably fabricate traversable wormhole time travel gates, where their starships would enter a wormhole in one region of space- time, and pop out in another extremely distant region of space-time.

According to the equations of general relativity, one of the mouths of the wormhole has to accelerate away from the other mouth to a very high speed close to that of light and then return. If you step into the mouth that accelerates and returns, you will step out the other end into the relative past of when you entered. If you step into the unaccelerated mouth and leave through the accelerated one, you will jump into the

relative future. That is, if you had an identical twin who did not go through the wormhole, your twin would be older than you.

How do you create a traversable wormhole time machine? Theoretical physicist Jack Sarfatti, has also been working on that question. A self-described “*rogue scholar*,” Sarfatti has had a long association with fringe science. He and Michael Murphy organized and led the first Physics of Consciousness Seminars at the Esalen Institute back in 1974, sponsored by former human potential movement superstar turned pariah, Werner Erhard. Those Esalen seminars spawned an entirely new genre of pop science literature, known as “The New Physics” — of which the recent best seller by Deepak Chopra, *Quantum Healing*, is but one example.

Sarfatti’s unorthodox theories on faster-than-light (superluminal) communication continue to raise hackles among the more conservative physics mainstream. When it comes to traversable wormhole time machines, Sarfatti speculates that so-called dark matter, which may comprise over 90% of the mass of the universe, could provide an answer.

This elusive matter has so far remained unobservable directly by conventional methods employing photons of electromagnetic radiation. Yet, its gravitational effects on ordinary matter are observed indirectly. “If dark matter moves around in the imaginary time of quantum gravity, then it would be difficult for it to emit any photons,

even if it wasn't electrically neutral. So, we wouldn't expect to see it through optical telescopes," Sarfatti explains.

The distinction between imaginary time and real time is important to clarify here. The late Nobel laureate, physicist Richard Feynman, was attempting to unify the quantum theory with gravity — for some time a kind of Holy Grail to physicists. His intuitive genius led him to reformulate the quantum theory as “a sum over histories.” According to Feynman, a particle doesn't just have a single history, as it would in classical Newtonian and Einsteinian physics. Instead, it is supposed to follow every possible path in spacetime.

There are two numbers that are associated with these histories, one for the size of the wave, and the other for its position, or phase, in the cycle. The probability that a particle can be found at any particular point is then found by adding up the waves associated with *every possible history that passes through that point*.

The problem is that when you actually perform this summing of all possible histories, severe technical problems arise. “To avoid the technical difficulties with Feynman's sum over histories,” says physicist Stephen Hawking in *A Brief History of Time*,

“one must use imaginary time... That is to say, for the purposes of calculation, one must measure time using imaginary numbers, rather than real ones. This has an interesting effect on spacetime: The

distinction between time and space disappears completely... we may regard our use of Euclidean spacetime as merely a mathematical device (or trick) to calculate answers about real spacetime.”

Despite the fact that imaginary time is only a calculational device, history has time and again that real physics can and does emerge from such abstract mathematical constructs of the mind. Nevertheless, all theories must still be verified by experiment for them to be meaningful. That is the nature of physics and the scientific method.

Sarfatti employs this same “trick” of imaginary time in his calculations on the possible nature of dark matter.

“I’ve been investigating a new kind of causality violating quantum field theory, which reveals that the projection of imaginary time motion into real time can be both slower and faster than light. If that’s true, it means that the energy density of this hypothetical neutral dark matter would get smaller as its speed increased, which would make it the perfect stuff to construct traversable wormholes with.”

He believes it might also make a super-efficient starship fuel. Remember the exhaust speed limitation of rocketry discussed earlier?

“In theory, dark matter can produce a faster-than-light exhaust velocity, which means it could be used to overcome the Einstein barrier. Since its density would theoretically decrease as its exhaust

velocity increased, that means a small amount of dark matter fuel could easily propel a massive payload to the stars,”

says Sarfatti.

“And, if dark matter is as uniformly distributed throughout the universe, as it seems to be, you’d never run out of fuel. Even though dark matter comprises 90% of the mass of the universe, its average density is still too small for us to detect directly in an easy way. But I think that situation will change in the near future.”

Sarfatti admits that a number of important questions about dark matter remain unanswered.

“How do we find and use such matter if it only exists in imaginary time? How does curvature in imaginary time influence curvature in real time? Can it be both attractive and exotic? Can dark matter carry electric charge? Does it have a magnetic moment? If it does, then it could be electromagnetically manipulated. And finally, is it even possible to scoop up and clump together enough dark matter with the accuracy and precision required to fabricate a traversable wormhole or power a starship?”

Combine an inexhaustible fuel with a potential faster-than-light exhaust speed, like the hypothesized dark matter, with a super-technology capable of manipulating space-time geometry, and you

have all the physical requisites for a starfaring society. If UFOs are interstellar in origin, then, they could be using traversable wormholes, or, they have developed an efficient interstellar propulsion system (like Sarfatti's proposed dark matter model), which allows them to travel very close to the speed of light. Traversable wormholes are preferable, since they would enable the extraterrestrials to *tunnel* across vast interstellar distances, and then tunnel back to where *and when* they came from.

Since the first version of this article, Alcubierre has shown how exotic matter permits an effectively faster-than-light [warp drive](#). The “ufo”, or starship, freely floats along a gravitational shock without time dilation. John Von Neumann, the mathematical genius and father of the programmable computer, hypothesized that sufficiently advanced extraterrestrial civilizations would be capable of constructing artificially intelligent robot probes to scour the universe. These intelligent *Von Neumann probes* would also be capable of universal replication. They would be programmed to utilize whatever elements they encountered in their travels to fabricate endless copies of themselves. After a long enough period of time had elapsed, the galaxies would be teeming with them. Von Neumann's hypothesis is often used as an argument against the existence of starfaring extraterrestrial societies, since we'd have likely already encountered their intelligent probes if any such advanced civilizations were out there.

If UFOs are not artificially intelligent Von Neumann robot probes, and if they are not using traversable wormholes, then, they're probably migrating as completely self-contained interstellar colonies. Since they would be traveling extreme distances close to the speed of light, they would find a much changed world from the one they left if they eventually returned.

According to the equations of special relativity, the closer you get to the speed of light, the more space-time contracts for you — what's known in relativistic physics as *space-time dilation*. The clocks aboard your starship run much slower than your friends' clocks back home. The result of all this is that your friends age and die much faster than you. Assuming an extraterrestrial psychology and society even vaguely similar to human society, with family and social ties as important as they are in human society, then the lack of time travel technology seems to necessitate the interstellar migratory colony mode of travel. For intergalactic gypsies, home is where you are.

A strong case has been made that after over 30 years of searching for extraterrestrial intelligence (SETI), we just have not observed the kind of infra-red and electromagnetic signals that a number of prominent scientists believe would be characteristic of an advanced extraterrestrial civilization capable of cosmic scale engineering and interstellar expansion. So, at this point in the evolution of the universe, humanity may truly be alone. That *fact* weakens the case for UFOs being purely extraterrestrial in origin from advanced alien civilizations

much older than our own. If UFOs are not extraterrestrial, then what are they? Sarfatti suspects

“They could be terrestrial time ships, originating from our own future. In which case, their motivation might be to interfere in their own past in order to assure their own coming into being in a globally and logically self-consistent way.”

British cosmologist Sir Fred Hoyle calls such acausal, circular connections *loops in time*. A number of papers have been published in respected physics journals that implicitly lend new credibility to this scenario, e.g., “Quantum mechanics near closed time-like lines,” *Physical Review D*, November 15, 1991 by Oxford’s David Deutsch, and “Wormholes in space-time and their use for interstellar travel,” *American Journal of Physics*, May 1988, by Cal Tech’s Michael Morris and Kip Thorne.

NASA’s Cosmic Background Explorer (COBE) satellite recently revealed small ripples of one part in one hundred thousand in the angular distribution of the cosmic background microwave thermal radiation left over from the Big Bang. These observed ripples, possibly the remnants of ultra-microscopic quantum fluctuations when the universe was even smaller than a single electron, might provide the mechanism for galaxy formation. This important new observation gives us a picture of the universe as it was only about three hundred

thousand years after the initial moment of creation of real time out of imaginary time.

Sarfatti conjectures that the quantum ripples observed by the COBE satellite may have been created from the far future, in a cosmic scale loop in time by an ultra-advanced intelligence, quite possibly evolved from us. A quantum optics experiment he had published a few years ago in *Physics Essays* could actually test that idea in the laboratory.

“If it works as the equations predict, it would be possible to build a kind of quantum telescope that probes the future just as a classical telescope probes the past. The power of prophecy would no longer be the exclusive domain of mystics, psychics, and avatars. It would be technology.”

But how do we go from hypothetical extraterrestrial or future-terrestrial super-technology, to present-day terrestrial engineering? In order to even begin to answer that question, we have to embark on a short trip through relativity theory and quantum mechanics.

Physics can be simplified by thinking in what's called inertial frames. In an inertial frame, the gravitational force is canceled out, and free particles move in straight lines with constant velocity. Obviously, the surface of the earth is not an inertial frame, because we feel gravity. In contrast, a freely floating non-rotating space shuttle orbiting the earth is an inertial frame.

The intuitive basis of the general relativity theory of gravity is something known as *the equivalence principle*. One version of this equivalence principle says that a small non-inertial frame, like a rocket or a UFO that is uniformly accelerating in empty, flat space-time, far away from all large masses, is equivalent to a non-inertial frame at rest, like an observer on earth. Whenever speaking of physical equivalence, it is assumed that the observers agree not to look outside their laboratory window or porthole of their spacecraft. If they closed their eyes, or only looked at their gravimeters, then, they could not decide which frame they were in. They would be in *locally equivalent frames*.

Einstein showed that mass curves spacetime, and that those non-spinning, local inertial frames, in which you are weightless, follow special *geodesic* world lines. A geodesic is simply the straightest path possible in a curved four-dimensional space-time. A skydiver in freefall is riding along a geodesic world line. You age more on a geodesic than on a non-geodesic. Conversely, one must apply non-gravitational forces (like muscles and motors) to move along a world line that is not a geodesic.

We now come to Jack Sarfatti's **new key idea** in understanding the physics of hypothetical UFO maneuvers. The geodesic is highly curved in three-dimensional space and corresponds to what a non-inertial observer on the earth sees as accelerated motion. However, observers living on the geodesic, like those in a UFO, experience a comfortable free float weightless condition throughout their apparent high-speed,

high-acceleration curved-motion. That leads to a second version of the equivalence principle: a small enough free floating or free falling local inertial frame in geodesic motion near a large mass, is equivalent to an inertial frame in flat space-time that is far away from any large mass. That means, if we see a UFO make a sharp right angle turn at very high speed, we can't jump to the conclusion that the inhabitants are feeling enormous g forces, if they have technology capable of controlling their local space-time curvature.

Imagine you are an astronaut in the space shuttle orbiting the earth. Gravity is canceled out. You are weightless. Again, you are simply following the straightest possible path, or geodesic, in curved four-dimensional space-time. Your frame of reference is locally inertial. As far as you can tell you are not accelerating. You feel no forces. You are in free float. Give a short gentle push to an object floating in the shuttle, and it moves at constant speed in a straight line.

In contrast, relative to a non-inertial, gravity bound observer down at Mission Control, Houston, you are rapidly accelerating towards the center of mass of the earth. It is only your conserved orbital angular momentum that prevents you from crashing into the earth. That is essentially the explanation given by Newtonian classical mechanics. However, in Einstein's classical theory of general relativity, you are moving locally on a geodesic, in the straightest path possible in curved four-dimensional space-time. The curvature is primarily caused by the mass of the earth.

We can now begin to see how what looks like a right angle turn at enormous acceleration to a non-inertial observer on the surface of the earth, might feel like nothing special to the freely floating inertial passengers aboard the UFO. That's because the UFO isn't being propelled in the familiar sense. It's simply freely floating in a locally bent space-time geodesic in its immediate neighborhood.

"If UFOs are really spacecraft, then somehow they're controlling their local space-time curvature, maybe in angstrom thin boundary layers fitting the outside surface of the UFO like a skin," speculates Sarfatti.

"And if that's true, they're probably doing it using loops in time. It's just a hunch." Then he added, "You know, when these things are really pumping up their local curvature engines, let's say during a high speed, right angle turn, standard Fourier signal analysis says that they're going to be generating significant broad band gravitational radiation. It happens that John Clauser at UC Berkeley is building a new type of ultra-sensitive atomic beam gravitometer that should be able detect just such radiation. Maybe his device could be used as the first bona fide UFO detector."

A prerequisite for UFO propulsion may be the principle of *global self-consistency*, or logical consistency, used by Kip Thorne and Igor Novikov in their traversable wormhole-time travel papers. This same key principle was independently discovered by Sarfatti and published in *Physics Essays*, Vol. 4, N^o3, Sept. 1991, in a paper provocatively

titled, “Design for a Superluminal Communication Device.” Sarfatti’s gedankenexperiment, which he no longer believes will work without a significant coupling between mind and matter, attempted to use the *quantum spin correlation* between special types of photon pairs, as a communications channel. This spin correlation is non-local, that is, faster-than-light.

Correlation, according to the equations of quantum mechanics, means that each photon in every pair is permanently entangled with its photon twin. Interfere with one photon, and its twin is always affected. The correlation persists regardless of the distance between the photon pair. This spooky, telepathic-like effect, known as the Einstein-Podolsky-Rosen effect, has actually been observed in a number of different atomic physics and quantum optics experiments.

Since an earlier version of this article was published in UFO Magazine, Henry Pierce Stapp, a physicist at Lawrence Berkeley Laboratory, published a remarkable paper in the prestigious Physical Review A (July, 1994, PP 18–24). Stapp cites an experiment by Helmut Schmidt involving **psychokinetic distortion of the statistical prediction of orthodox quantum mechanics that works precognitively backwards in time** on radioactive nuclear decays! A theorem by Stapp’s Berkeley colleague, Philippe Eberhard, shows that Sarfatti’s prediction cannot work with an ordinary inanimate physical device that obeys the statistical predictions of **orthodox** quantum mechanics. Nobel Prize physicist, [Brian Josephson](#) has suggested

that **only living matter can violate the statistical predictions of quantum mechanics and, thereby, use the nonlocal quantum connection as a practical communication channel** the way Sarfatti claims to “remote view”. Sarfatti now agrees with Josephson because of Stapp’s July 94 paper.

What does all this quantum weirdness have to do with UFO propulsion? A young Canadian physicist- engineer, Lyle Fuller, had an important insight after reading Sarfatti’s *Physics Essays* paper. In a series of letters to Sarfatti, Fuller mathematically argued that any attempt to create a time travel paradox with Sarfatti’s proposed electro-optical device, or any other type of superluminal signaling device, would cohere the normally random and hidden, but infinite zero-point quantum vacuum energy into coherent space-time curvature. The hypothetical release of that energy would then change the geometry of space-time in such a way that the possibility of paradox will always be prevented.

When we speak of the quantum vacuum, we don’t mean a vacuum in the ordinary sense of an empty void, but rather the opposite — an infinite reservoir of virtual particles and energy. It is known that vacuum zero point energy exists, but at present there is no feasible way of utilizing it. The basic idea of the connection between zero-point energy fluctuations and gravity was first recognized by the Russian Nobel physics laureate and political activist, the late Andre Sakharov.

Roger Penrose argues against this view in *Shadows of the Mind*. On the other hand [Hal Puthoff](#) is working on Sakharov's theory.

Extrapolating from Fuller's argument, Sarfatti speculates that UFOs could be employing some kind of “**paradox engine**,” or “**curvature generator**.” By continually generating paradoxes, this engine would force nature to avoid paradox by releasing inexhaustible quantities of zero point vacuum energy, physically altering the geometry of spacetime — a starship fueled by paradox. Obviously, the demonstration of such a device would dramatically prove that the preservation of global, or logical consistency is a fundamental and immutable law of nature. It would also probably fill our planet's energy needs forever. In other words, energy may be mutable, but logic is not. Nature abhors a paradox.

Sarfatti considers a paper by David Deutsch published in the November 25, 1991 *Physical Review D* to be a milestone.

“Deutsch explicitly shows that influences from the future constrain initial conditions on the classical level, and yield a globally self-consistent pattern of probabilities at the quantum level,” he explained.

“That's why the thermal radiation ripples observed by the COBE satellite could be an intelligently created artifact from the future. But here on the laboratory scale, any of our clever attempts to create time travel paradoxes will likely cause one of the following three things to

happen: Either laboratory equipment or people will malfunction with certainty — in which case free will is an illusion, isn't it? Or, zero point energy will be released, physically changing space-time curvature in such a way as to always avoid paradox. Or, as David Deutsch suggests, the universe will simply split.”

Verification of any of these admittedly speculative hypotheses in the laboratory would make the debate over UFOs moot — we could make our own starships.

Archonialis

Enlightenment for those who are curious **Sunday, 8 December 2024**

Time Travel

The Possibility of Time Travel: A Journey Through Science and Imagination

Time travel has been a captivating subject in science fiction, philosophical discussions, and scientific speculation for decades. The ability to traverse through time—whether to visit the past or glimpse into the future—challenges our understanding of physics, causality, and existence itself. But is time travel truly possible? To answer this question, we must explore the realms of theoretical physics, examine philosophical paradoxes, and consider technological advancements.

The Nature of Time

To understand time travel, we must first define time. Time is often perceived as a linear progression from past to future, measured by clocks and experienced subjectively. Albert Einstein's theory of relativity revolutionized this understanding, showing that time is not an absolute, independent entity but a dimension intertwined with space, forming a four-dimensional spacetime continuum. Events that are simultaneous to one observer may not be so to another, depending on their relative motion.

Relativity also introduced the concept of time dilation, where time moves slower for objects traveling at speeds close to the speed of light or in strong gravitational fields. This phenomenon has been experimentally verified and hints at the malleability of time—a prerequisite for time travel.

Theoretical Frameworks for Time Travel

Several theories suggest mechanisms by which time travel might occur. While none have been proven feasible with current technology, they provide intriguing possibilities:

1. Wormholes and Einstein-Rosen Bridges

Wormholes are hypothetical shortcuts through spacetime, connecting two distant points. In theory, a wormhole could also connect two different times. If one mouth of the wormhole were accelerated close to the speed of light or placed in a strong gravitational field, time dilation could create a time differential between the two ends. A traveler entering the wormhole could potentially emerge in the past or future.

However, wormholes face significant challenges. They require exotic matter with negative energy to remain open and stable, and their existence has yet to be confirmed. Moreover, quantum effects might render them highly unstable.

2. Closed Timelike Curves (CTCs)

Proposed solutions to Einstein's equations of general relativity, such as the Gödel metric, allow for closed timelike curves. These are paths through spacetime that loop back on themselves, theoretically enabling time travel. While mathematically sound, CTCs often require conditions, like rotating universes or exotic matter, that seem unrealistic.

3. Time Dilation and Relativity

Time dilation, as observed in relativistic physics, is a form of "time travel" into the future. Astronauts traveling at near-light speeds or residing near massive gravitational bodies (as depicted in *Interstellar*) would experience time much more slowly than those on Earth. This phenomenon is well-documented but limited to forward-only time travel.

4. Quantum Mechanics and Multiverse Theory

Quantum mechanics introduces the possibility of alternate timelines or parallel universes. The "many-worlds" interpretation suggests that each decision or quantum event spawns a new universe. If time travel to the past were possible, it might involve entering a parallel universe rather than altering one's original timeline. This concept circumvents some paradoxes but remains speculative.

Philosophical and Logical Challenges

Time travel, particularly to the past, presents numerous paradoxes that challenge logic and causality:

1. The Grandfather Paradox

If a time traveler goes back and prevents their grandparents from meeting, they would never exist to make the trip. This paradox questions whether changes to the past are logically possible.

2. The Bootstrap Paradox

In this scenario, an object or piece of information is sent back in time and becomes the cause of itself in the future, creating a causal loop with no clear origin. For example, imagine receiving a book from the future, publishing it, and then sending it back in time.

3. Free Will and Determinism

Time travel also raises questions about free will. If the future can influence the past, does that imply a deterministic universe where events are predestined?

Philosophers and physicists have proposed various solutions to these paradoxes, including self-consistency principles (events are predestined to avoid contradictions) and the idea that past-altering time travel might be impossible within our universe.

Technological and Practical Considerations

Even if time travel is theoretically possible, the technological hurdles are immense. Building a wormhole, manipulating spacetime, or achieving relativistic speeds would require energy scales far beyond anything humanity can currently produce. The creation of exotic matter or advanced quantum technologies might one day bridge this gap, but such advancements remain speculative.

Furthermore, practical issues like the targeting of specific times, ensuring biological safety during time travel, and accounting for Earth's movement through space add layers of complexity.

Evidence for and Against Time Travel

While time travel remains speculative, some phenomena and theories fuel the debate:

1. Time Travelers Among Us?

Anecdotal claims of time travelers—such as mysterious figures in historical photographs or predictions of future events—are often debunked as hoaxes or coincidences. However, they capture the public imagination.

2. Hawking's Chronology Protection Conjecture

Stephen Hawking argued that the laws of physics might inherently prevent time travel to the past, safeguarding causality. For instance, quantum effects could destabilize wormholes or other time-travel mechanisms.

3. Experimental Evidence

Experiments like those involving atomic clocks on high-speed jets or the behavior of particles in accelerators have confirmed time dilation, supporting relativity's predictions. However, these findings only validate forward time travel under specific conditions.

The Cultural and Ethical Implications

The possibility of time travel carries profound cultural and ethical implications. Revisiting the past could allow historians to witness events firsthand but might also risk altering history.

Traveling to the future could inspire humanity with visions of progress or lead to despair over potential dystopias.

Ethical considerations also arise: Who should have access to time travel? How would its misuse be prevented? The answers to these questions depend on the specifics of the technology and societal values at the time of its development.

Time travel remains an alluring concept at the intersection of science, philosophy, and imagination. While the theories of relativity, quantum mechanics, and advanced physics provide tantalizing possibilities, significant scientific, technological, and philosophical hurdles must be overcome. Whether or not time travel becomes a reality, its exploration enriches our understanding of the universe and our place within it. Until then, it will continue to inspire dreams, stories, and scientific inquiry.

UFO Propulsion System - Bending time and space

UFO Propulsion System - Bending time and space

Defense Scientists and Engineers are finally starting to understand the ultimate propulsion system that can make instantaneous space travel possible. The UFOs use this propulsion system to travel great distances instantaneously.

The speed of light is 670,000,000 miles per hour – a number no human being can ever stand in any craft for a long time. Does that mean UFOs are unmanned or extra-terrestrial beings are totally different? It is possible but not likely. Theory of evolution in the Universe says that intelligent life forms are abundant in the Universe but they have evolved in a similar way.

Traveling even at the speed of light (670,000,000 miles per hour) is just not enough to cover distant destinations in the Universe. For example even at that speed traveling from one constellation to another may take hundreds of years.

Then how can one travel such great distances in a short span of time? This is the million-dollar question that has made every country in the world keep quiet about UFOs and cover up their existence and interaction. Every country believes they will be the first to uncover the technology of “flash travel” which is the term used in traveling from point A to point B in the Universe instantaneously.

To understand the concept, imagine you have to travel from New York to New Delhi, two points in the opposite sides of the globe. Now think you have the technology of freezing time and then get back to current time. At 9AM (or any other time of a particular day), you take the instance of the globe and freeze it for travel. Now assume the globe is made of paper or some other flexible material. Now you deform the globe and bring NY and New Delhi touch each other. Then travel from NY to New Delhi instantaneously because the distance is really very little since you deformed the globe. After completing the travel you put the globe back to its original configuration. And you transfer yourself to the current time.

This may seem complex but actually once the technology is mastered it is really simple. Another way to understand this is to hold a piece of rectangular paper in your hand. Bring the two opposite corners of the rectangular piece of paper together and make them touch each other. Now the distance between the two opposite corner is really zero.

Bending space and time is the concept where you do not travel to the destination; you bring the destination close to you. This is exactly how UFOs travel from one destination to another. That is the reason why those who are waiting with their telescope in the open sky to find UFOs will never find them.

Scientists and Engineers are now perplexed trying to understand how that kind of space travel is possible. The answer lies in using something known as dark energy. The dark energy allows disintegration or deformation of space. There are some early indications that dark energy also allows isolating time dimensions.

Physicists and Engineers are researching the use of dark energy. The purpose is to understand the process of bending the space and time. That requires UFO flight patterns; sighting information and a mathematical algorithm to back calculate their flight positions in a more than three dimensional geometry. Computer models are helping. We do not have the technologies to capture or isolate time dimension. Can you draw a block or a cube on a piece of paper? Yes, you can. It is called an isometric drawing

It is the process of drawing a three-dimensional drawing on a two dimensional paper. Similarly, complex algorithms are allowing reverse engineering the UFO Time and Space bending in a medium that is three-dimensional. The resulting map is showing the space and time (four dimensions) in a three dimensional environment.

Sometimes you wonder what any one can gain spending so much time and money to hide and cover up all the UFO information? Why so much ridicule around something every country is running after since 1890? The answer is the fact that any one who can master this time and space bending technology will be ahead of others by many years.

There are early indications that scientists and engineers have got an early indication to the concept of bending time and space using dark energy. Interestingly, the whole concept starts with Einstein’s Theory of Relativity.

Time Dilation Calculator

Table of contents:

- [What is time dilation? — Time is relative](#)
- [The time dilation formula](#)

The **time dilation calculator** gives you a better idea of the time behavior according to special relativity.

Einstein's relativity theory has shown that **time is relative**. Time perceived by one observer in its frame of reference differs from that of another observer in another inertial frame. Please keep reading to find out what time dilation is and what happens to it when we approach the speed of light 🕒

What is time dilation? — Time is relative

One of Einstein's special relativity theory's implications is that **time is not absolute but rather relative**.

The example of two inertial observers, A and B, each carrying a clock, is frequently used to illustrate this relateness aspect of time. If observer A remains stationary while observer B travels relative to A, B will see A's clocks moving slower than theirs. Similarly, A will perceive B's clock to be going slower — **Observers perceive that a clock moves slower when it moves relative to them**.

This effect of the time slowing down is known as **time dilation**. The faster the relative velocity between observers, the greater the time dilation is, becoming more evident when speed approaches values in the order of magnitude of the speed of light. In **special relativity, the principle that the speed of light is constant** for every observer is essential, as it explains why time has to dilate in order for the speed of light to remain the same regardless of the observer's own motion.

Another common thought exercise used to explain time dilation is the **twin paradox**. In this imaginary situation, one twin travels into space in a high-speed rocket while his sibling stays on Earth. The astronaut-twin moves at a speed closer to the speed of light and, after some years, returns to Earth. Once back on Earth, the astronaut-twin finds his Earth-twin has aged lots more than he has.

You may wonder what the paradox is in this situation. The paradox arises when we consider the astronaut-twin to be the one that's stationary and the Earth-twin the one that's relatively moving. In this case, the Earth-twin would be younger than the astronaut. So, why is it stated that it's Earth-twin who has aged more? The reason for this is that these situations are not symmetrical. The astronaut-twin is undergoing a non-inertial movement (accelerating and decelerating during his journey), while his brother is moving in a non-accelerated relative motion.

To learn more about relativity and the relationship between mass and energy, visit the [e = mc² calculator](#)!

💡 Did you know there's another form of time dilation known as gravitational time dilation?

The time dilation formula

Time dilation is determined as the difference of time perceived by the moving observer and the stationary observer $\Delta t'$. The **time dilation formula** based on special relativity is:

$$\Delta t' = \gamma \Delta t \quad \Delta t' = \Delta t \sqrt{1 - v^2/c^2} \quad \Delta t = \gamma \Delta t' \quad \Delta t = \Delta t' / \sqrt{1 - v^2/c^2}$$

where:

- $\Delta t'$ — Time that has passed as measured by the traveling observer (relative time);
- γ — Lorentz factor, $1/\sqrt{1 - v^2/c^2}$;
- Δt — Time that has passed as measured by a stationary observer;
- v — Speed of the traveling observer; and
- c — Speed of light (299,792,458 m/s).

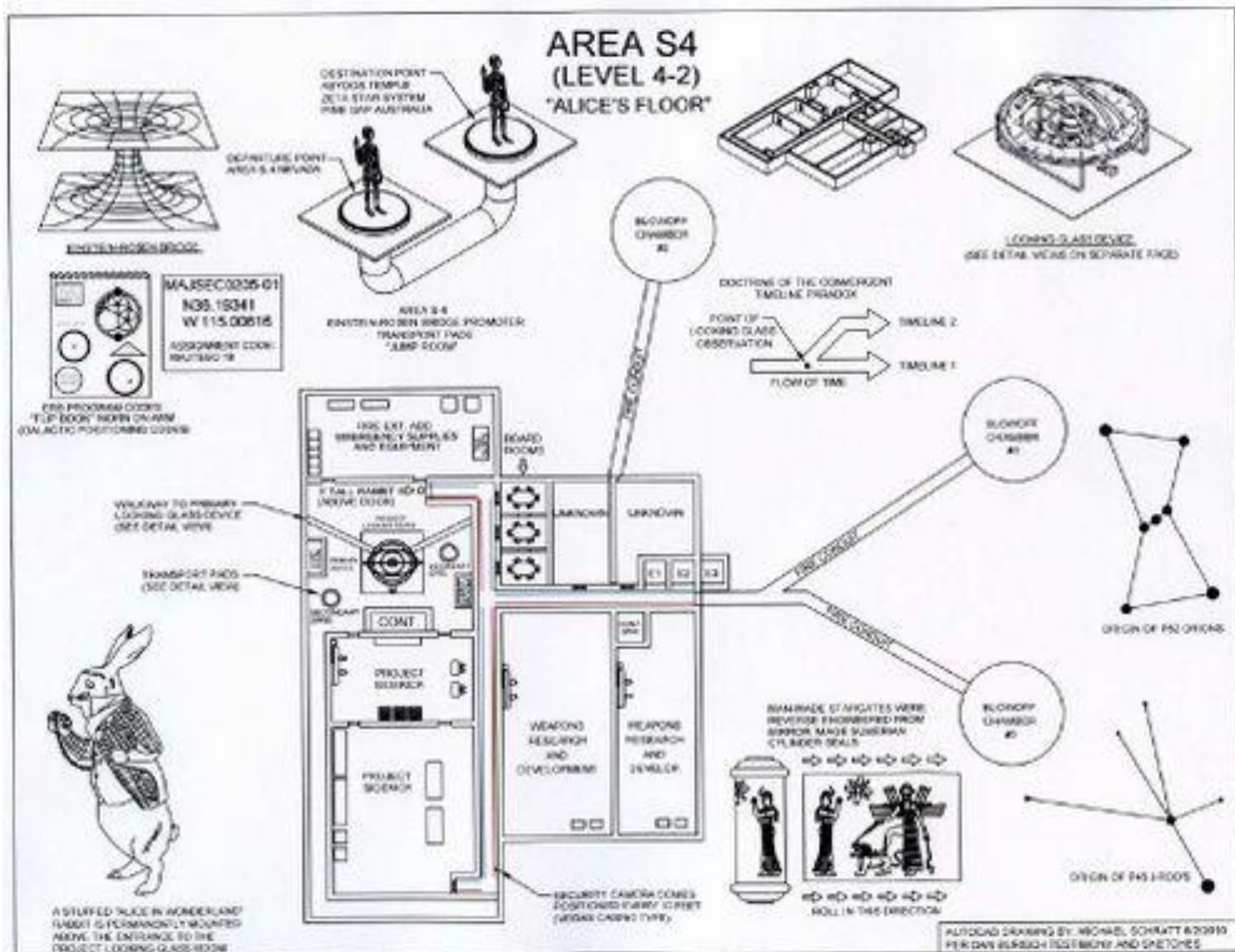
You can learn more about the Lorentz factor of a moving object with the [Lorentz factor calculator](#).

This is the expression used by the time dilation calculator ⌚ Notice that **for this time difference to be evident, the speed v must be at least in the order of magnitude of the speed of light** to obtain any substantial difference in times observed by moving and stationary observers.

Nevertheless, the time dilation effect has been proved at speeds many orders of magnitude lower than the speed of light. This is the case of an experiment conducted in 1971 using three sets of atomic clocks. One of them remained on Earth while the others flew aboard two different airplanes. The results showed a difference in times elapsed by all sets of clocks.

💡 Give the time dilation calculator a try! What happens to time dilation values when you enter a speed of $0.001 c$ and then $0.9 c$?

Project Looking Glass



Area **S-4 facility** Level 4-2 diagram, also known as "Alice's Floor," where one of the **Looking Glass devices** was allegedly held.

Project Looking Glass is a purported [secret government program](#) investigating [time travel](#), [stargate technology](#), and methods for viewing probable future events through artificially induced phenomena. The program allegedly involved advanced devices derived from back-engineered extraterrestrial technology, developed and operated under the aegis of [Majestic 12](#) and related organizations. Testimonies from various sources, notably [Dan Burisch](#), describe the project's aims, operations, and eventual decommissioning, along with its role in predicting possible global events.^{[1][2]}

History

According to testimonies provided by whistleblowers such as [Dan Burisch](#), Project Looking Glass was developed in the mid-to-late 20th century as part of a suite of secret government initiatives, including [Project Aquarius](#) and other programs at the [Area 51](#) facility in [S-4](#), Nevada.^{[3][4]} The project aimed to harness [Einstein–Rosen bridge](#) (ERB) and [wormhole](#) technology to observe probable future events and explore the physics of time distortion.^[5] Research and development were reportedly influenced by ancient [Sumerian cylinder seals](#), which were said to encode plans for constructing such devices.^{[6][7]}

Technology

Project Looking Glass centered around a complex machine designed to bend [space-time](#) and view events across different timelines. The device incorporated multiple spinning rings of electromagnets, a rotating cylinder or barrel, and injected gases such as [argon](#) to create a pearlescent sphere that projected holographic-like images.^{[5][8]} It was back-engineered from instructions supposedly found on [Sumerian cylinder seals](#), allowing researchers to recreate [stargate](#)-like technology.^[6]

The Looking Glass functioned by warping local space-time using artificially produced [gravity waves](#), projecting visual and auditory representations of potential future events. It was often operated in tandem with a second similar device to enable acoustical signals, as two units were required for audio reception.^{[9][10]}

Development and operation

Throughout the 1960s to 2000s, research on Project Looking Glass was conducted at highly secured facilities such as [Area 51](#)'s [S-4](#) base.^{[11][4]} According to Burisch's accounts, the project was managed by high-level officials from the [Majestic 12](#) group. In the case of at least one employee, [Bill Uhouse](#) at [Los Alamos](#), it involved face-to-face interactions with [crash-landed](#) and retrieved [Grey aliens](#) who came to be known as [J-Rods](#) who provided technical guidance. The program also explored the [convergent](#)

[timeline paradox](#), studying how observation of future probabilities could influence outcomes.

Purpose and capabilities

The primary purpose of Project Looking Glass was to forecast potential future events and evaluate the probabilities of various outcomes. The device could display multiple possible futures, which operators statistically analyzed to determine the likelihood of events occurring.^{[12][10]} These capabilities extended to studying how artificial manipulation of [wormholes](#) and [stargate technology](#) might influence global events such as wars, natural disasters, and geopolitical shifts.^{[1][5]}

Testimonies indicate that data from the Looking Glass was used to predict events such as the [9/11 attacks](#) and the potential for an Islamic extremist war with the United States, with probabilities assigned based on device readings.^{[1][13]} However, these predictions were subject to interpretation and debate among insiders.

Decommissioning and aftermath

By the early 2000s, concerns about the potential misuse of the technology and catastrophic outcomes prompted efforts to dismantle Looking Glass and related stargate devices.^{[2][10]} Devices were collected, components separated, and handed over to international entities such as the [United Nations](#) and [NATO](#) for safe storage to prevent proliferation.^[10] The decommissioning was seen as a preventative measure to avoid triggering a predicted global catastrophe associated with the activation of these devices during significant celestial alignments.^{[14][6]}

Notable figures

Among the individuals associated with Project Looking Glass is Dr. [Dan Burisch](#), a former researcher at [Area 51](#) who provided extensive testimony about the program.^{[2][15]} His collaborator, [Marcia McDowell](#), also contributed testimony and insights.^[3]

Context about Burisch's experiences, including his interactions with other secret projects and concerns over the implications of [Looking Glass technology](#), are documented in various interviews and publications.^[16] While not an expert in the technology, his and others' testimony has contributed to detailed descriptions about the devices and technical specifications and their situation within [S-4](#).^[17]

Legacy and influence

Project Looking Glass has influenced narratives in popular culture, where themes of [time travel](#), futuristic predictions, and secret government projects are explored.^[6] The concept of using advanced technology to observe and potentially alter future probabilities relates [quantum mechanics](#) and [multiverse](#) theories and allegations of [parallel](#) or [alternate timelines](#).

Numerous interviews by alleged witnesses and information developed, notably by [Project Camelot](#), have touched on the scope and legacy of Project Looking Glass and humanity's quest to understand and control its potential futures. ^{[18][19][20][21][13]}

According to the alleged insiders, The Looking Glass technology was apparently used to look backward and forward in time, using the consciousness of an operator as a type of steering mechanism. The operator would sit in a chair that was apparently recovered from a downed extraterrestrial craft capable of interfacing with consciousness directly.

When the device was turned on, strong toroidal fields of energy cycled about a pouch of water at the center, which acted as a sort of resonator for in-streaming energies from the point of focus maintained by the operator. The data was collected and projected onto video monitors at incredible speeds, which later needed to be de-interlaced to reveal discernible images.

What's interesting, is that the biases of the operator would have a direct effect on the images collected. For example, if one were to look back to the time of Jesus' crucifixion if the person doing so was an atheist, they may not see anything at all. But if the person was a Christian, they may see the infamous crucifixion event.

This is suggestive of a time-space mechanic in the universe, wherein the human mind is able to navigate through time itself. The work of Dewey B. Larson and his Reciprocal Systems theory provides the basis for this interpretation.

Briefly, the universe as described by Larson is broken up into two physical regions, as defined by motion.

Below the speed of light, motion operates in three dimensions of space and one dimension of time. Above the speed of light motion operates in one dimension of space and three dimensions of time. As bizarre as that sounds,

the mind is uniquely equipped to navigate in time, which is able to access memories of the past, gain awareness of events in the present, conceive of future possibilities, and even imagine alternative events that did not actually happen.

In other words, the human mind can select a point of focus, just like in Remote Viewing, and receive information from the store of memories made during experience. If a mind is properly trained, it can be used to access nonexperiential data in the same way one can recall a memory.

The Looking Glass device seems to be capable of the same type of process, to access a data stream from any conceivable location in space or time, steered via the consciousness of an operator.

According to Burisch's testimony, technology was provided to the human race during Sumerian times, when an advanced contingent of future humans went back in time and provided civilization assistance after a cataclysm known as the deluge. The Sumerian cylinder seals were encoded with plans to build the Looking Glass device.

Earlier versions of the project saw the development of an actual portal that an individual could move through to jump in time.

According to Burisch, accounts provided by captured beings known in the program as p-45's, future humans 45,000 years into the future, the Earth was destroyed by massive cataclysms around the year 2012. This was apparently because Looking Glass devices were actively being used during a major celestial alignment, which overloaded the organic energy grid of the planet.

Burisch further claims that the device has been dismantled as a result of discovering two probable timelines, one of which is the cataclysm described by the captured being.

An attempt was made to look into the future, but no concrete data was able to be received past the infamous date of December 21st, 2012, suggesting that this date is a nexus point in time, whereby either timeline one or timeline two would gain momentum. In the last report, Burisch suggested that timeline one, the positive timeline, had an over 80% likelihood of coming to fruition.

This is undoubtedly one of the more intriguing topics in awakening times, which seems to be well hidden in popular works of fiction.

Corey Goode, a secret space program insider, claims to have reviewed documentation relating to this project.

The Commentary that follows is from my [Bill Hamilton's] source that linked with inside sources and took notes on *Project Looking Glass* (LG) and Time Travel experiments: "With regard to LG (*Looking Glass*): As I understand it, this device (at least 3 to 4 years ago) could not focus on a detailed sequence of activities in the future. In other words, you could not see exactly what would happen, like a series of events. I was told to consider the multiverse idea combined with work by **Richard Gott** on cosmic strings.

The *multiverse* apparently is accessed when the forward mode is set. I was also told to consider the views provided by LG as one of many potential realities (at least in the future view mode). I have also been told that recently there has been an effort made to outfit videotape recorders to be sent forward through the apparatus, thereby allowing the dark project people to gain some insight into what may take place.

When I heard about this several questions came to my mind. The most pressing of which was: if a camera were sent forward in time/space, would it be able to record anything other than what was immediately in front of its lens? I mean, what if LG were located in the middle of the Groom Lake facility, and the operators wanted to gain insight into the outcome of a conflict, say in the Middle East.

How could a videotape recorder, set to record what was right in front of its lens at that location gather any data on the Middle East if it were still stuck in the middle of the Mojave desert when it got to the future??

Hell, something important could be happening right behind the camera and it would miss it – a couple of degrees change in camera direction allows one set of events to be seen while another set is completely overlooked, much less events half a world away. To answer this question, my contact was not specific, saying only that cameras did not move, as mass does not change in its perspective to space-time.

However, such an item placed into the injected atmosphere might experience a different time, if only briefly. Cameras could film within the gas or see images in the injected atmosphere as though it were a lens reflecting events in and around the column. I was given the understanding that the tilt or positioning of the electromagnets would allow different views or positions in the environment to be reflected in the gas column

I feel confident that at least *two rings of electromagnets* are employed and that the rest of the device is composed of a barrel and the gas injected into the barrel – Two different sources have indicated that these are the basic components – These magnets spin in different directions, creating a charge of some kind.

Then the gas is injected into the barrel. Depending on the direction of the spin – I am sure speed and tilt and a bunch of other factors must also have an effect – *time and space* can be warped forward or backward by long or short distances relative to the present. I have reason to believe that the scientists have completed a map of the exact positions and speeds of the magnets necessary to reach targeted times both forward and back.

Apparently, images of the events at different places, relative to the location of the device can be picked up and in essence reflected off the gas, causing it to behave like a teleprompter or *crystal ball*, for lack of a better example.

But I am not entirely sure that mass does not move, or that mass is not affected. Since I was also told many years ago about an experiment that went very wrong in the early years of the LG project, involving a test subject of some kind. As I understand it there was significant movement of mass during that experiment, and it ended up with a rather gruesome death for the poor test subject.

I originally thought it was a monkey, but I found out that there were many test subjects that got sent through, so I am not certain what kind was involved in the experiment that went bad. However, in my typical reverse-logic search for corollaries, this tells me that there must have been many test subjects that made it through just fine. So I am certain that any errors that were made or any miscalculations have long since been corrected.

I wish I could offer you more information. For what its worth, my sources have confirmed the presence of electromagnets and a barrel-like device which is

injected with some kind of gas....these components seem necessary for LG to function as a viewing device.

And as for any changes in mass, or movement within time-space.... I really don't know since my information sources would only tell me 'so much about what they saw or experienced at the time they were involved. But it can be reasoned, based upon what they did say that there were significant experiments in the movement of mass back and forward through time, many of which were successful. I am sure much has been discovered and/or refined in the process since then."

The numbers that we received before Looking Glass was shut down, and disbanded, were that there would be a 19% probability with an 85% confidence, that the disaster would occur, and that there would be *a transition from Timeline 1 to Timeline 2.*

But, that then means that there's an 81% chance that it won't. And so, the individuals who want to carry, the negative line, are convinced that it's going to occur, are not presenting the facts. The facts are: this is the material that we have available that we know.

Many whistleblowers have said the program was not actually shut down, just classified into deep black.

How the Universe's hidden 'scars' could unlock time travel

Nobody knows if cosmic strings exist, but if they do, they could change everything we know about the Universe.

Published: November 9, 2024

If the existence of cosmic strings is confirmed, it would be huge. They could help uncover the Holy Grail of physics: a theory of everything. And in the far future, they might even enable us to time travel.

The theories that predict their existence suggest that cosmic strings are thinner than an atomic nucleus. [Prof Ken Olum](#), of Tufts University, describes them as astronomically long tubes. "They would most likely exist in the form of either loops or long strings that go on and on forever," he says.

But while the strings are super thin, they can pack in a lot of mass. "A typical loop, which may be about 10–20 light-years long, can contain around the equivalent of the mass of tens of thousands of stars," says Olum. But it's thought they'd shrink over time as the tubes wiggle, radiating gravitational waves.

Confusingly, it's also thought that there are two different types of cosmic strings, although they'd behave in very similar ways. One type, called cosmic superstrings, is predicted by string theory, an unproven attempt at a theory of everything, suggesting the Universe is ultimately made up of tiny, vibrating strings.

Cosmic superstrings would essentially be the fundamental strings that produce all the matter in the Universe, stretched out.

The other type is envisioned as a scar from the early Universe. At its earliest stage, the cosmos was in a completely different state from the one it's in now. It was extremely hot and dense.

Physicists believe that the four forces of nature – electromagnetism, [gravity](#), and the strong and weak forces of the atomic nucleus – were merged into one single force at this point. But we don't know much about the strange physics going on at the time.

After a period of cooling and extremely rapid expansion, known as inflation, the Universe changed 'phase' to become a very different place. This involved particles forming and the forces breaking off from each other.

Such phase transitions happen in water, as it freezes or evaporates. [J Richard Gott](#), professor emeritus of astrophysics at Princeton University, says you could think of the phase transition as a 'melting' of high-density energy in space. "When snow melts, you can be left with a few snowmen still standing," he explains.

And that's, essentially, what cosmic strings are: areas of very high-energy density left behind during a cosmic transition from higher to lower energy.

Freezing is also a good analogy. If you fill an ice cube tray with water, you can see imperfections form while it freezes, including cracks and air bubbles. Cosmic strings would emerge in a similar way.

Physicists suspect cosmic strings could still be around today. However if we actually encountered one, which is unlikely, it might be unpleasant. A cosmic string travelling close to the speed of light and hitting Earth head-on would cut the planet in half, just like a wire cutting through a ball of clay. But one half would then immediately slam back into the other, according to [David Chernoff](#), a professor of astronomy at Cornell University.

In the best-case scenario, we could experience the equivalent of a magnitude 7 earthquake, says Chernoff. But it could produce a seismic event of up to around 12.6 magnitude – considerably bigger than the largest earthquake in history.

Searching the sky

The hunt is on to find cosmic strings. One approach is to look for spooky copies of the same galaxy or other bright objects. Because of their high density, the strings would cause

gravitational lensing. This happens when heavy objects warp the space-time around them and alter the path of light as it passes by.

A cosmic string would bend space-time into a cone-like structure. So if we were looking at a galaxy from Earth and a cosmic string appeared vertically in front of it, the light from the galaxy would be split – travelling on each side of the string. Meaning we should see two identical images of the same galaxy, a small distance apart.

There have already been reported sightings of this kind. In 2003, a team of astronomers reported the potential discovery of a cosmic string, but it was later proven that the two galaxies they had seen were not identical. Another such claim was made last year. But Olum warns that recent research suggests this method of spotting cosmic strings is far from ideal.

Cosmic strings were originally thought to be much denser than scientists believe today, having what physicists call high tension, or mass, per unit length. In fact, they were once thought to be responsible for forming structures such as galaxy clusters by gravitational attraction.

However, observations by Olum and others suggest the strings should be fairly light. That's because very dense strings should cause certain anomalies in the cosmic microwave background, the light left over from the [Big Bang](#).

But those haven't been spotted, suggesting the strings, if they exist, must be about 10,000 times lighter than scientists initially thought. And they couldn't be the main cause of matter clumping together in the Universe. But it also means they'd warp space-time so subtly, that you wouldn't actually be able to see two distinct images of galaxies, due to the gravitational lensing.

Chernoff has come up with a more promising method of spotting them called gravitational *microlensing*. Instead of looking at galaxies, which appear as fuzzy objects, he wants to spot lensing by observing individual stars.

Star light, star bright

Chernoff's proposal involves looking at stars in the Milky Way and nearby galaxies and monitoring their brightness. The theory is, if a string passes between us and a star, the light from the star would be gravitationally lensed by the string.

For a short period of time, two unresolved images of the star would appear in the sky – though they wouldn't be separately discernible. But there would be a sudden and detectable doubling of the star's brightness. In fact, a string passing in front of a star should increase its brightness by a factor of two for a few days, before it goes back to normal, explains Chernoff.

While he's started investigating some data, he's yet to find a cosmic string. The approach is considered speculative. How likely we are to find strings this way will depend on how fast they're moving and whether they're clustered in galaxies – things we don't know for sure. But there's optimism among physicists. "This is an interesting idea," says Olum, a view supported by Gott.

Chernoff himself is cautiously optimistic. "We're actually in a golden age for this experiment," he says. "The National Science Foundation, NASA and ESA are building these experiments to do exactly what we need, which is to repeatedly measure the light from large numbers of stars."

He highlights the Vera C Rubin Observatory, currently under construction in Chile, as promising. It will allow us to make a time-lapse movie of the sky, looking at 17 billion never-before-seen stars.

The Vera C Rubin Observatory could be a vital tool in the search for cosmic strings. Photo credit: aurore simonnet/nanograv, vera rubin observatory

If we do discover a string, the approach would be perfect for studying it. "Once you've detected a microlensing event, there's a whole bunch of other things that you can immediately do," says Chernoff, adding that the crucial advantage is that we'll know its exact location – pinpointed by an individual star. "So all the gravitational wave detectors could then be focused on a point in the sky."

The most promising data so far, however, comes from gravitational waves. Last year, the North American Nanohertz Observatory for Gravitational Waves, or NANOGrav, a

collaboration between teams based in the US, Europe, Australia and China, reported evidence for a background of gravitational waves with long wavelengths.

These were spotted by observing pulsars, rotating objects that emit pulses of radiation at regular intervals. But gravitational waves with long wavelengths, such as those thought to be produced by cosmic strings, can warp space-time in a way that makes the radiation from the pulsars irregular, allowing scientists to detect them.

The most likely explanation for the result is pairs of supermassive [black holes](#) orbiting each other as galaxies merge. That's because we know that black holes actually exist, unlike cosmic strings.

But is it the whole story? Long-wavelength gravitational waves kicking around in the galaxy may also come from other sources, including cosmic strings. The signal seen by NANOGrav may in fact be a cocktail of different types of gravitational waves.

When the team analysed the data, they were rather surprised. "The model of black holes doesn't fit well," says Olum who is part of the collaboration. The team went on to try and match the signal to various astrophysical sources and discovered that cosmic superstrings, the kinds predicted by string theory, fit the data well – better than black holes or the alternative type of cosmic strings.

The finding has led to a lot of excitement about the possibility that NANOGrav has discovered the first evidence for string theory. "We actually got a detection," says Gott. "That means we've seen something."

Olum remains cautious, however. "It could very well just be black hole binaries," he argues. "The next data set may show something different." Indeed, more data is likely to make the signal stronger and more reliable. But for that, we have to wait a few years.

Further ahead, the planned Laser Interferometer Space Antenna, LISA, will launch into space during the 2030s and continue the search for gravitational waves. "LISA is better matched to detect gravitational waves from cosmic strings than either NANOGrav or LIGO," says Chernoff.

The LISA probe could provide more telling evidence for the existence of cosmic strings.
Photo credit: Science Photo Library

Finding cosmic strings would be revolutionary – giving us important hints about what a deeper theory of physics would look like.

Not only may their detection give observational support for string theory, they might also provide a means to test so-called 'grand unified theories', which aim to describe the very young Universe, in which three of four fundamental forces (apart from gravity, you need a theory of everything for that) are united.

“There’s a huge number of grand unified models,” says Olum. “So even if we can just rule out some of them, that would help people know where to focus their attention.”

Cosmic strings could also help explain a series of recent, puzzling observations, including impossibly large black holes spotted by the James Webb Space Telescope. These beasts are so huge they must have grown faster than scientists thought possible. But it’s possible they may have been “seeded by the gravitational attraction of cosmic string loops in the early Universe,” says Olum.

The possibility of time travel

Could cosmic strings be practically useful? Scientists have long known that Albert Einstein’s theory of General Relativity allows loops in time to exist – possibly enabling time travel. This is because space-time can be curved until it closes in on itself and creates a loop.

Nobody has ever seen or built one, but such loops are a valid solution to Einstein’s equations. In 1991, Gott discovered that two moving cosmic strings could produce such a loop – and are an exact solution to the equations.

Heavy objects such as cosmic strings can bend space-time to create shortcuts in space-time. That’s ultimately what a wormhole is thought to be: a region connecting areas of space very far apart. “General Relativity says you can beat a light beam geometrically in a race if there’s a shortcut,” says Gott.

If you travelled between two planets, for example, and there was a cosmic string in the middle, this would create a shortcut compared with travelling straight between the points.

If you took this route and travelled near light-speed, you'd be able to arrive at your destination faster than a light beam travelling straight between the two planets. That means when you arrived at your destination, you'd be able to watch yourself packing your bags at your starting point.

Gott showed that two cosmic strings travelling in opposite directions, and crossing each other, would warp space-time in such a way that it would create a time loop. If you travelled around the two strings, you'd go back in time.

But this would require both the spacecraft and the strings to travel at 99.99 per cent of the speed of light, which is hard to achieve. And it's unlikely that a pair of infinite strings, which are rarer than loops, happen to exist in such close proximity.

"You're very unlikely to find an infinite string moving that fast in the observable Universe; they typically move at around half to 70 per cent of the speed of [light](#)," says Gott. "But the reason we're investigating this is we want to uncover clues as to how the Universe works."

"There's nothing wrong with his maths," says Olum, although he remains sceptical about the possibility of ever building a time machine. "If your Universe doesn't have this time machine already, you can't just take some matter and use it to make the cosmic strings proposed by Gott," he explains. "The strings would have to stretch across the whole Universe. So it's not very useful in terms of building a time machine."

The secrets of the Universe

Gott admits it would be hard to build a time machine in this way. But he believes there may be another way. Rather than using infinitely long strings, we could use a finite string loop in the shape of a rectangle, with two very short sides and two enormously long sides (potentially thousands of light-years long).

The next step would be to let the loop collapse. "You can manipulate this loop by moving massive spaceships around it," he suggests, adding that "we're talking about super civilisations here."

This movement would stretch and drag the loop around until it collapsed into a black hole, bringing the sides towards each other at near light-speed. This would be an analogous situation to the time machine he presented in 1991, except that this time the solution wouldn't be exact, just approximate.

"So if your civilisation agrees to collapse a time loop around you, what you have to do in your spaceship is wait until the sides of the loop get close." And they could get very close – millimetres apart. You would then fly around the strings to visit your past.

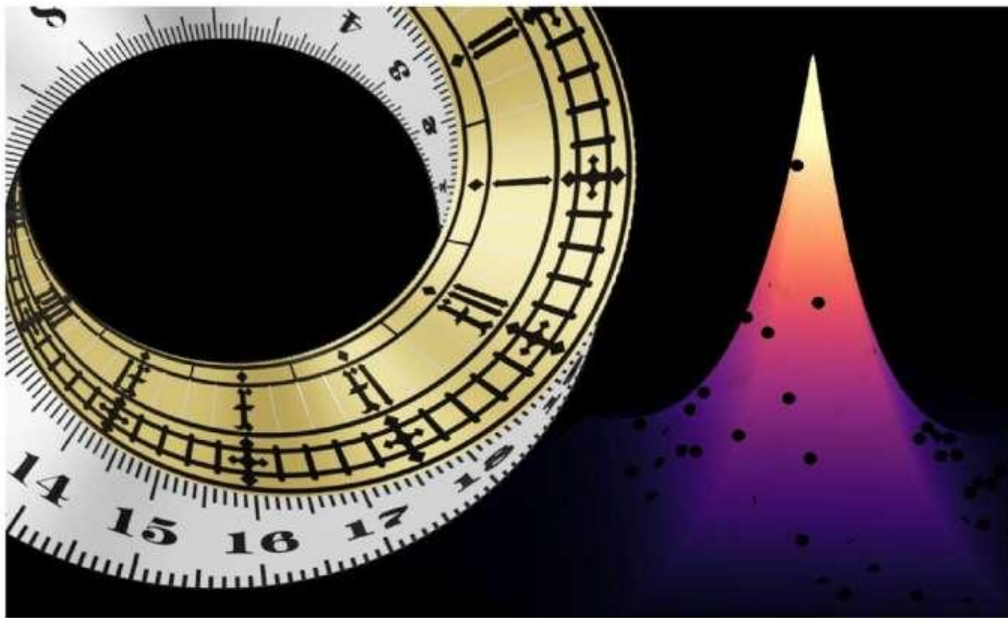
There are downsides, though. "You'll find yourself trapped in a black hole, so you can't get back out to tell your friends about your adventures," he says. It would also be technically challenging. According to Gott, the time loop would need a mass corresponding to about half a galaxy.

The thought is dizzying. But to most physicists, including Gott, the alluring thing about cosmic strings isn't their potential for time travel. It's the fact that they may help uncover the secrets of the Universe on the most fundamental scales. Let's just hope one doesn't pass too close and slice Earth in half before we decode those hidden secrets.

APRIL 23, 2025

It's about (space-)time: Scientists explore new dimension for light

by Kirstin Werner, [University of Rostock](#)



Time and space rethought: A new look at these old dimensions in physics opens doors to new phenomena, such as so-called space-time-topological events, and their technological applications. Credit: A. Szameit/ Universität Rostock

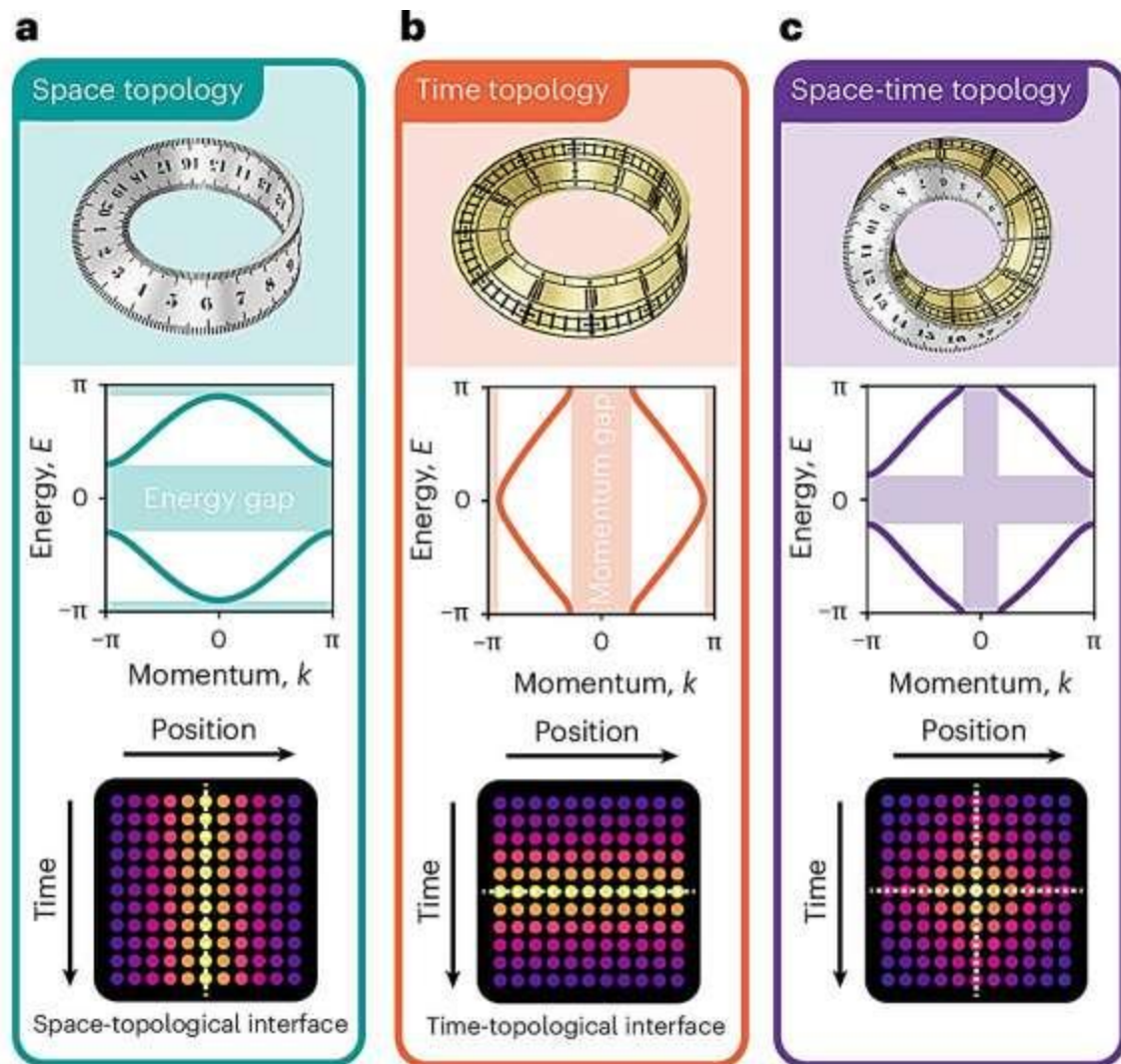
By breaking a decades-old paradigm and rethinking the role that the dimension of time plays in physics, researchers from the University of Rostock and the University of Birmingham have discovered novel flashes of light that come from and go into nothingness—like magic at first glance but with deep mathematical roots that protect against all kinds of outside perturbations. Their [findings](#) have now been published in the journal *Nature Photonics*.

Time is the strange dimension: Unlike its spatial siblings, it is a one-way street as the clock only ever ticks forward and never backward. Scientists have long been aware of time's quirks, with the British astrophysicist Sir Arthur Eddington musing about this "arrow of time" in his 1927 lectures. Nevertheless, whether it be because of or despite its uniqueness, time as a dimension for physics to play out in has long received far less attention than space.

Recently though, rapid progress in the research on so-called spatiotemporal crystals, objects with repeating patterns in time and space, has inspired a rethinking of the role time should play in our understanding of physics. Additionally, this has spawned the question of

whether the uniqueness of time can be more than a mere quirk and instead lead to new effects ultimately useful in applications.

Now, a team of researchers from the University of Rostock and the University of Birmingham has taken up this challenge and made a crucial discovery: In their experiments, light is brought to appear glued to a singular point in [space-time](#). "It's almost biblical: In the beginning, there is nothing. Then physics says, 'Let there be light!,' and there actually is light—at one precise moment in time and point in space," says Prof. Alexander Szameit of the University of Rostock.



Space, time and space-time topology. Credit: *Nature Photonics* (2025). DOI: 10.1038/s41566-025-01653-w

These fleeting flashes of light, however short, are no accident, but instead have deep mathematical roots, elaborates Prof. Hannah Price of the University of Birmingham: "Topology, a perhaps rather abstract but very fundamental and deeply consequential branch of mathematics, actually mandates certain physical behavior here."

Because of this and due to the one-way nature of time, such space-time-topological events, as they are called, also exhibit a unique robustness against outside perturbations: The researchers found that they come with an inherent protection against randomly messed-up experimental parameters as well as stray light.

"This is something seemingly all previously known states of light are susceptible to," Dr. Joshua Feis of the University of Rostock explains.

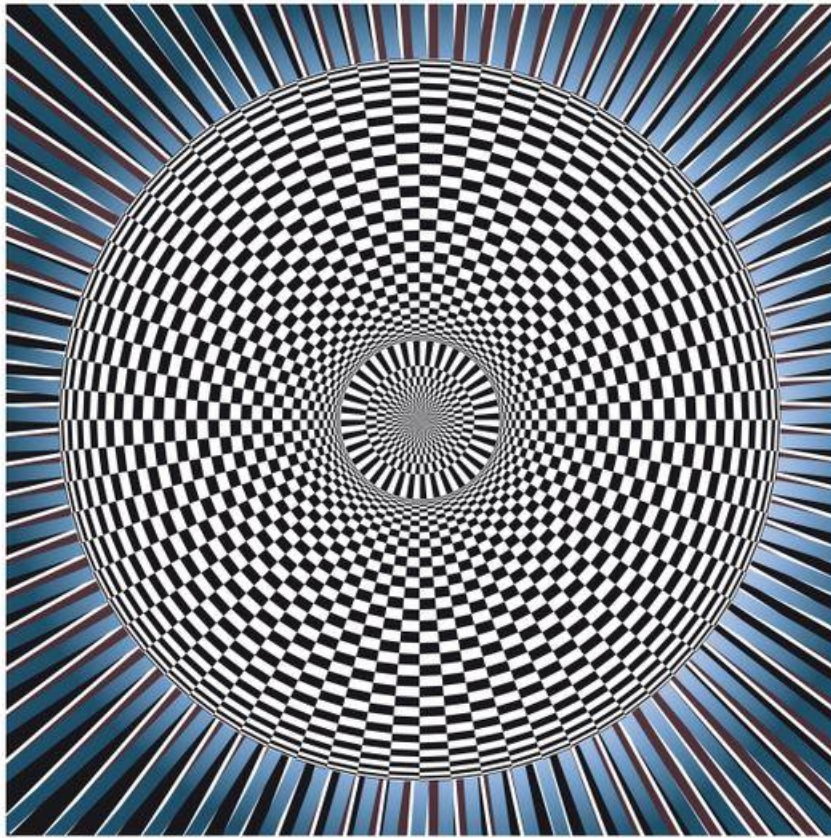
Dr. Sebastian Weidemann, also from the University of Rostock, adds, "Such protection is very desirable as it may allow the robust shaping of [light](#) waves in key applications such as imaging, communications or lasers."

These findings prove the potential that reconsidering the role of time in space-time, in physics in general as well as in its interplay with topology, has for both fundamental science as well as potential applications. Crucially, they open the door to a much wider field of potential discoveries enabled by directing research into this new-old dimension.

More information: Joshua Feis et al, Space-time-topological events in photonic quantum walks, *Nature Photonics* (2025). DOI: [10.1038/s41566-025-01653-w](https://doi.org/10.1038/s41566-025-01653-w)

Journal information: [Nature Photonics](#)

Provided by [University of Rostock](#)

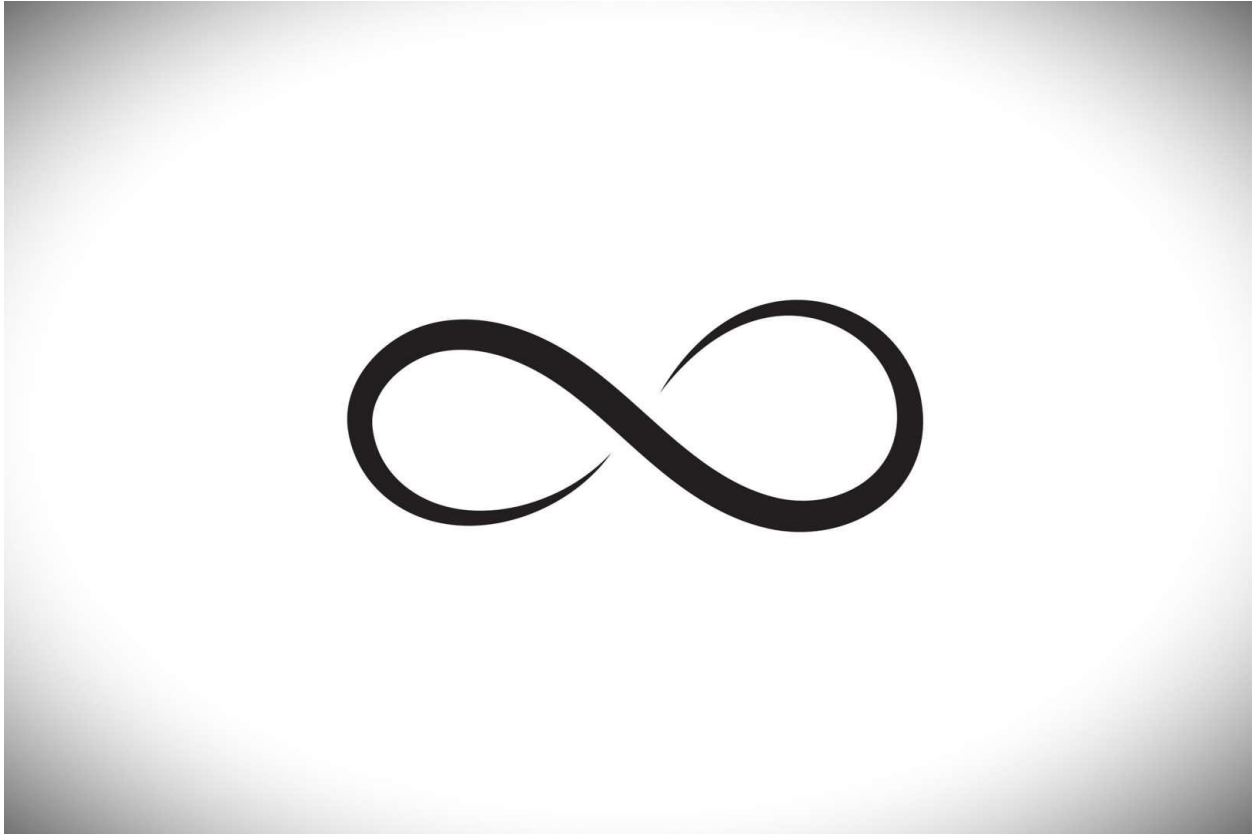


What is infinity?

Infinity has captivated human thought for millennia. It has challenged [philosophers](#), mathematicians, scientists, and theologians alike, and is a concept that stretches beyond the limits of comprehension. Not only does it appear in numbers that never end, but also in the question of how far the universe extends and the boundlessness of moral duties.

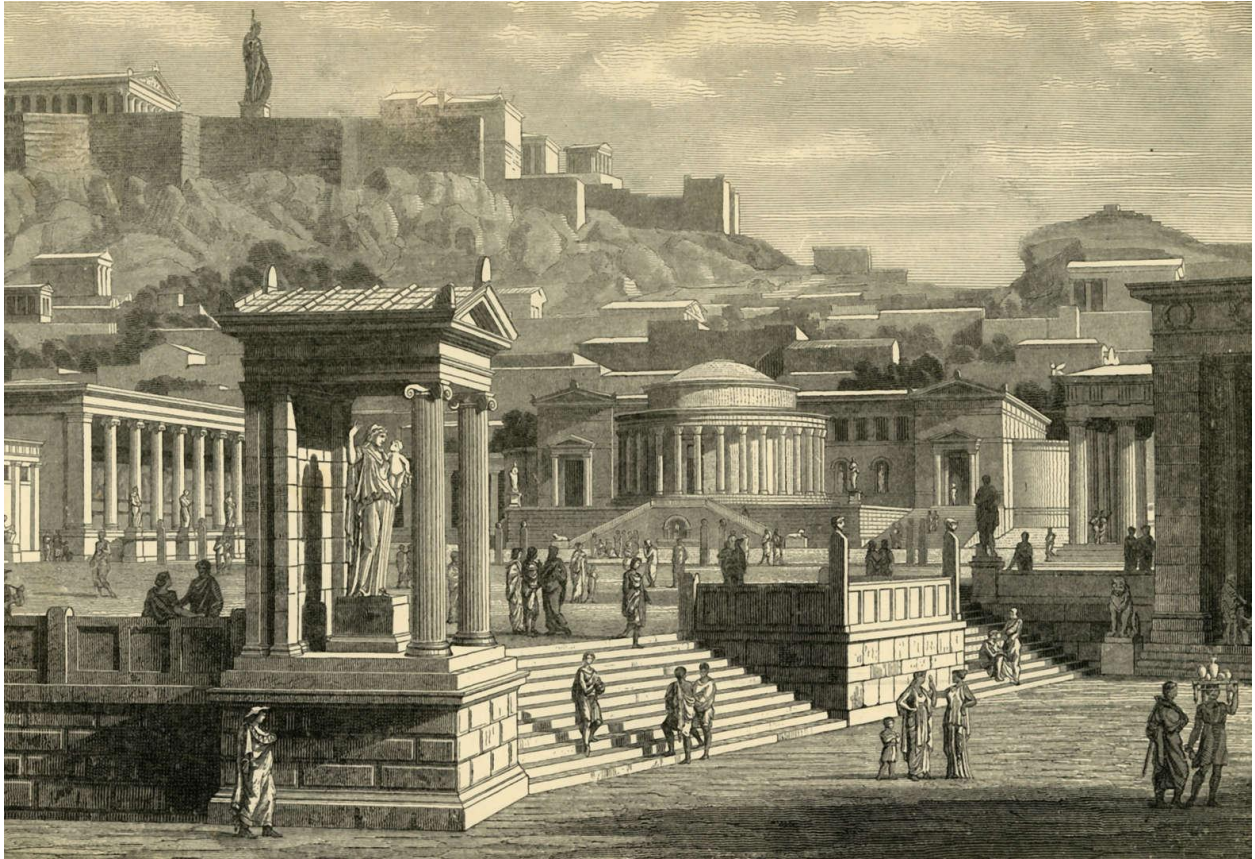
Some of history's most celebrated philosophers, like Aristotle and Zeno, have questioned whether infinity was a real phenomenon or just a useful idea. Others have tried to logically define the infinite, and even modern scientific advancements have tried to put an answer forward in groundbreaking ways.

How can humanity hope to understand something that has no end? What exactly is infinity? And is it something real, or is it just an illusion? Click through this gallery to see what philosophy has to say on the matter.



The infinite enigma

The concept of infinity is truly the embodiment of the limitless, the boundless, and the immeasurable. Despite centuries of exploration, infinity remains a paradox and continues to challenge human perception while shaping theories about the universe and our existence within it.



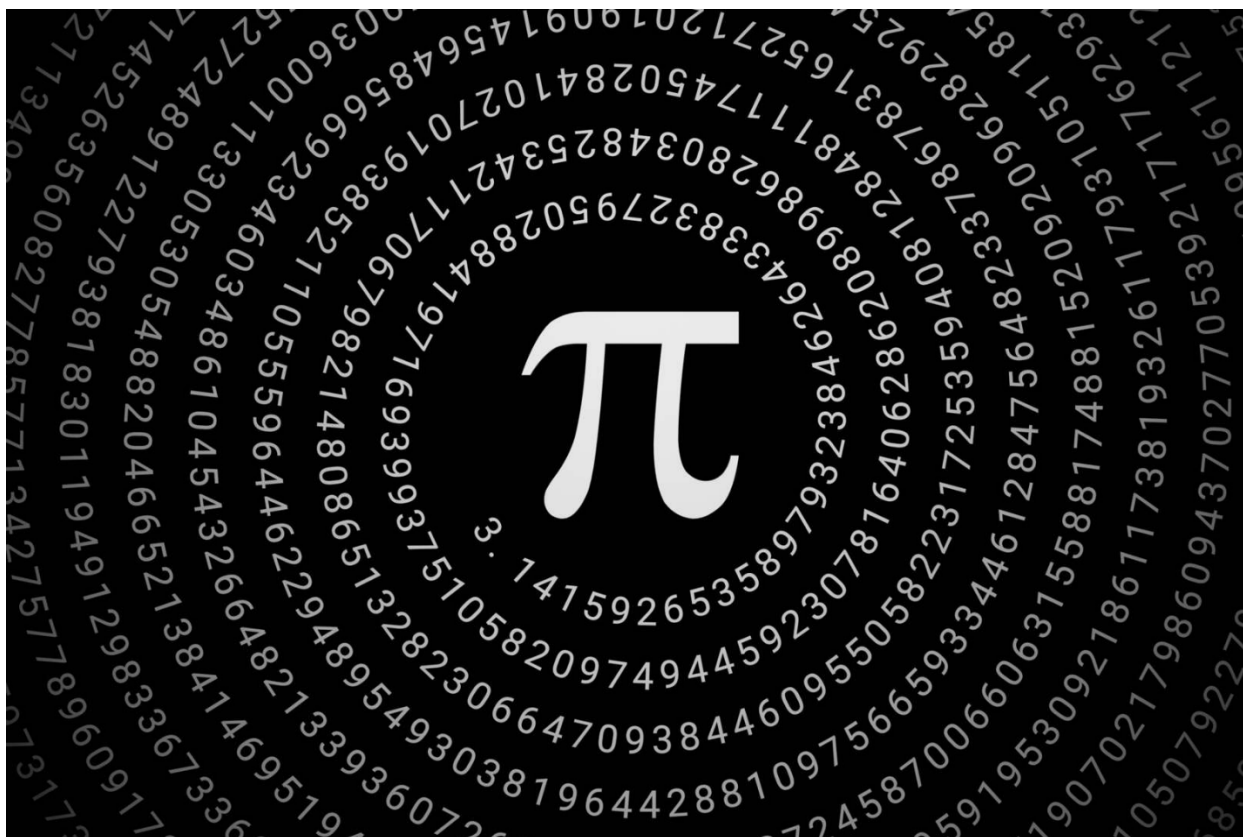
The Greeks

Ancient Greek philosophers laid the foundation for discussions on infinity, each offering unique perspectives. Some saw infinity in nature, while others viewed it as a purely mathematical idea. These early explorations sparked an ongoing dialogue about whether infinity exists in reality or only in abstraction.



Anaximander's infinite Apeiron

The philosopher Anaximander introduced the concept of Apeiron, an infinite, boundless substance from which all things emerge and eventually return. This early idea of an unending cosmic cycle implied that existence is infinite, with creation and destruction forming part of an eternal, never-ending process beyond human understanding.



Irrational numbers

Pythagoras and his followers encountered infinity in mathematics when they discovered irrational numbers—values that never terminate or repeat, like pi. This challenged their belief that the universe was perfectly ordered, as they realized, the numbers could extend infinitely.

Theoretical vs. actual infinity

Famed philosopher Aristotle later distinguished between potential infinity (something that could continue indefinitely, like counting) and actual infinity (which existed as a complete, infinite entity). While he accepted the former, he struggled with the latter, arguing that actual infinity was logically problematic and could not really exist in nature.



Zeno's paradoxes

One of Plato's students, Zeno of Elea, presented [paradoxes](#) that questioned the existence of motion. He argued that if space is infinitely divisible, reaching any destination requires completing an infinite number of steps. Philosophers and mathematicians were forced to rethink whether infinity was a mental construct or a fundamental aspect of reality.

The theological turn

In medieval times, scholars linked infinity to theology, particularly in Christianity and Islam. They debated whether infinity belonged solely to God or if the universe also possessed infinite qualities. These discussions shaped religious and philosophical interpretations of boundlessness and even divine omnipotence.

God as the only true infinity

The Italian priest Thomas Aquinas argued that only God was truly infinite, since he possessed boundless power, knowledge, and goodness. While the universe seemed vast, Aquinas believed that it remained finite, a distinction that allowed medieval thinkers to reconcile their belief in a limitless divine creator with a limited physical world.

Grasping infinity

In the 12th century, Islamic philosopher Al-Ghazali doubted whether humans could truly understand infinity. He argued that reason alone could not comprehend infinite time, space, or existence. He asserted that only an infinite divine being could fully grasp the nature of boundlessness beyond human logic.

Rationalists redefine infinity

Rationalist philosophers such as René Descartes and Baruch Spinoza attempted to rationalize infinity, linking it to divine attributes, biology, and the fundamental nature of existence. They believed that the human mind naturally conceived of infinity, which made it not just a mathematical abstraction but an essential component of reality itself.



Infinite substance

Descartes argued that infinity must exist because humans can conceive of it. He introduced the idea of an "infinite substance," which he applied exclusively to God. He believed our awareness of infinity was evidence of God's presence, since a finite mind could not invent such a concept.

Radical unity

Spinoza added to this by proposing that God and nature were not separate but the same infinite substance. He believed that everything in existence formed part of an infinite whole, so divinity and the universe were one and the same thing. He called this *Deus sive Natura* (God or Nature).



Mirrors of the universe

Meanwhile, the German polymath Gottfried Wilhelm Leibniz introduced the concept of monads—tiny, indivisible units that make up reality. He believed these monads were in perfect harmony, working together in a way only God could fully understand due to their infinite complexity.

Infinity in the Age of Enlightenment

During the Age of Enlightenment from the 17th to the 18th centuries, people explored infinity beyond religion, viewing it through scientific and philosophical lenses. This shift led to new ways of understanding the infinite that shaped mathematics and even physics.



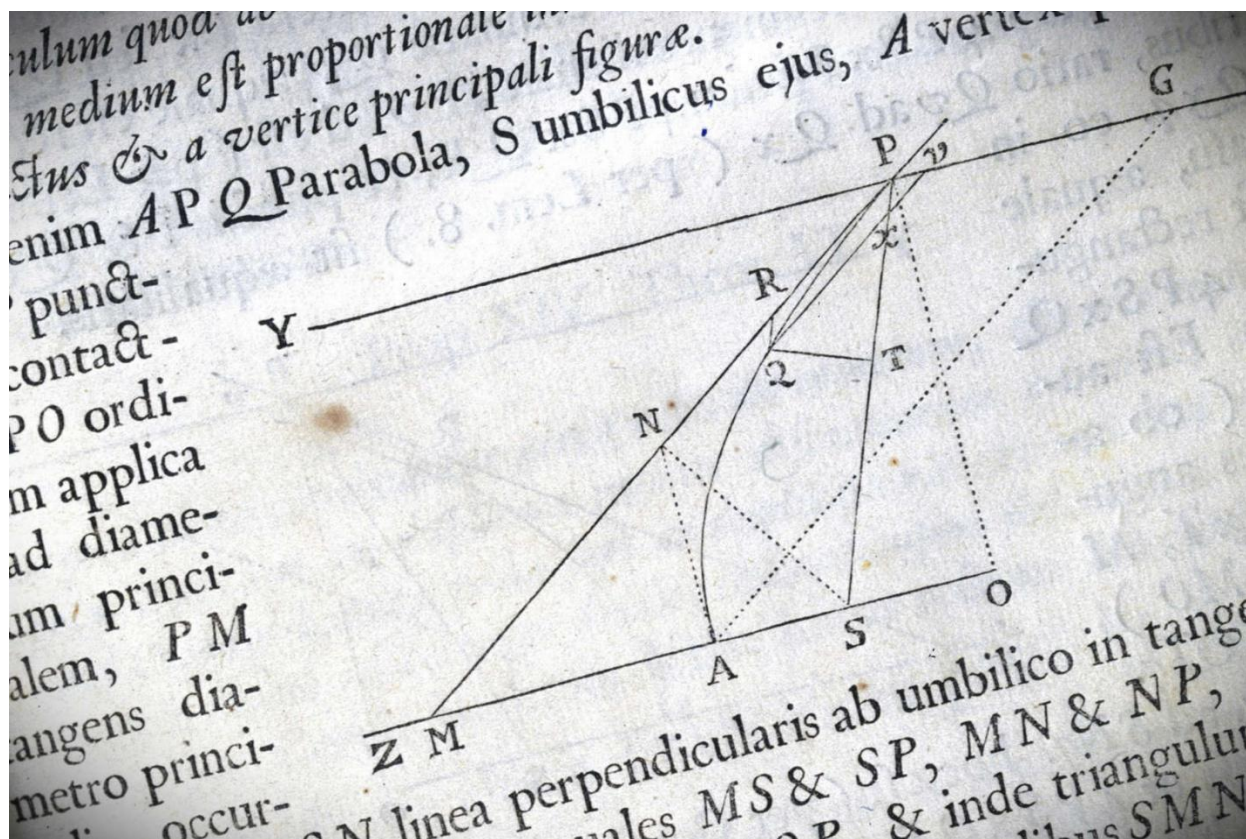
Infinity paradox

In the 1700s, German philosopher Immanuel Kant revealed contradictions when it came to reasoning about infinity. He argued that the existence of both a finite and an infinite universe led to logical dead ends. This showed that human reason was incapable of fully grasping the true nature of infinity.



An unresolved dilemma

Kant posed a paradox: if the universe were finite, what lay beyond? If it were infinite, how could something extend without limit? His work emphasized that both ideas led to contradictions that might be beyond human comprehension.



The birth of calculus

In order to try and explain infinity from a mathematical perspective, some intellectuals took a scientific approach. Isaac Newton and Leibniz independently developed calculus, a groundbreaking mathematical system that used infinitesimals—values that are infinitely small yet never reach zero.

Turning infinity into a tool

©Getty Images

Calculus allowed people to solve problems involving motion, change, and curves, which turned infinity from an abstract puzzle into a practical tool for science and engineering.

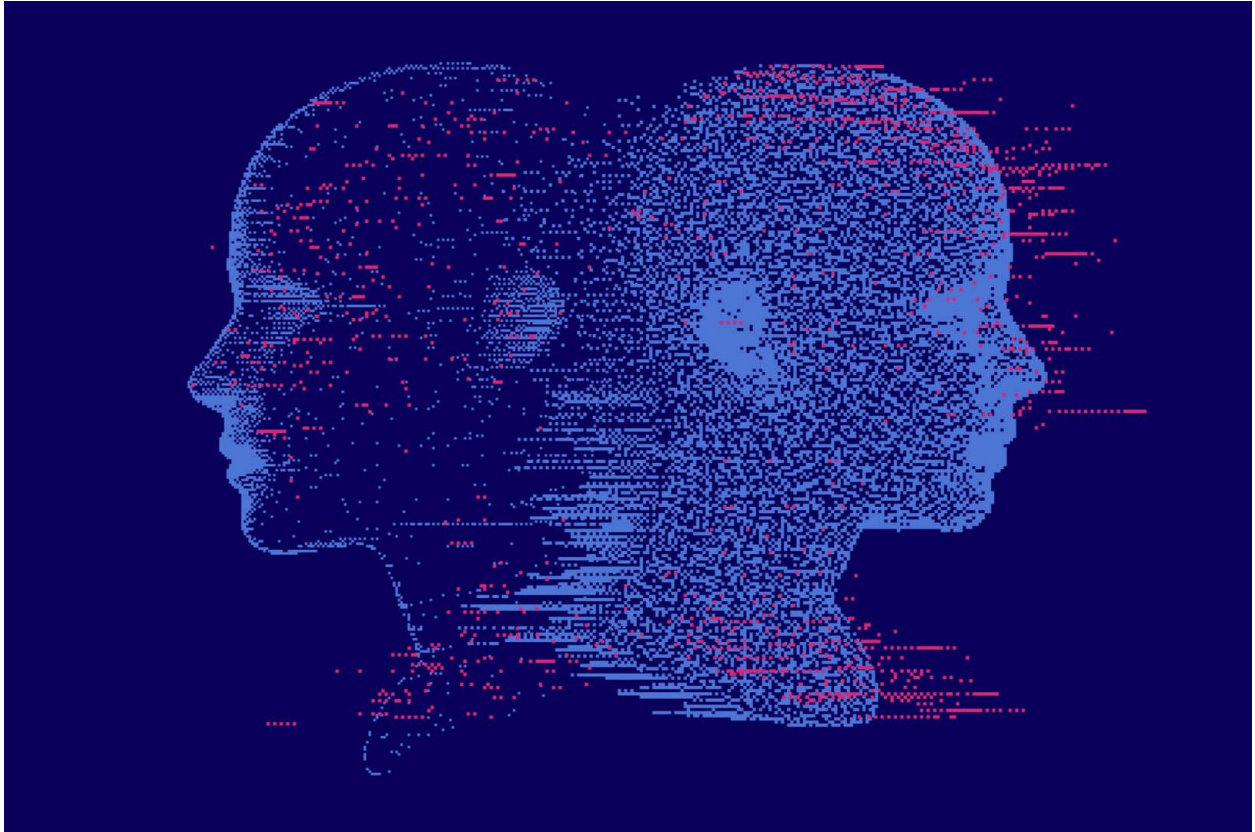
An existential approach

As humanity moved into modernity, philosophers like Jean-Paul Sartre viewed infinity from the perspective of existentialism and what infinity means for the lives of humans. This approach diverged drastically from classical discussions on the topic.



The existential burden of choice

Sartre believed people were “condemned to be free,” since humans face an endless array of choices. The infinite possibilities of action places an unbearable weight of responsibility on each individual to define their existence.



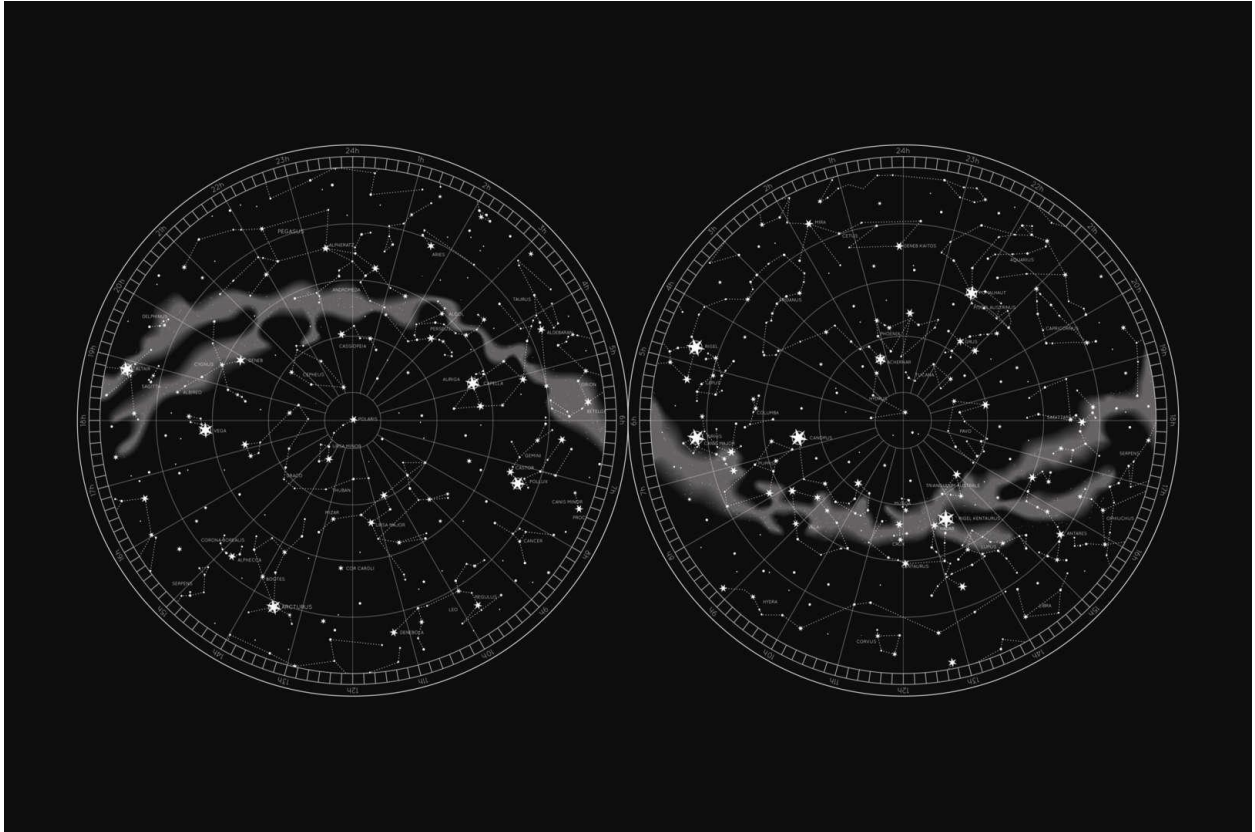
The never-ending flow of perception

Edmund Husserl, the founder of phenomenology, examined infinity in human consciousness, and he argued that perception is an infinite, ever-expanding process. Since experiences continuously build upon each other, a person's consciousness remains in an eternal state of development, which makes subjective reality an unending horizon of awareness and understanding.



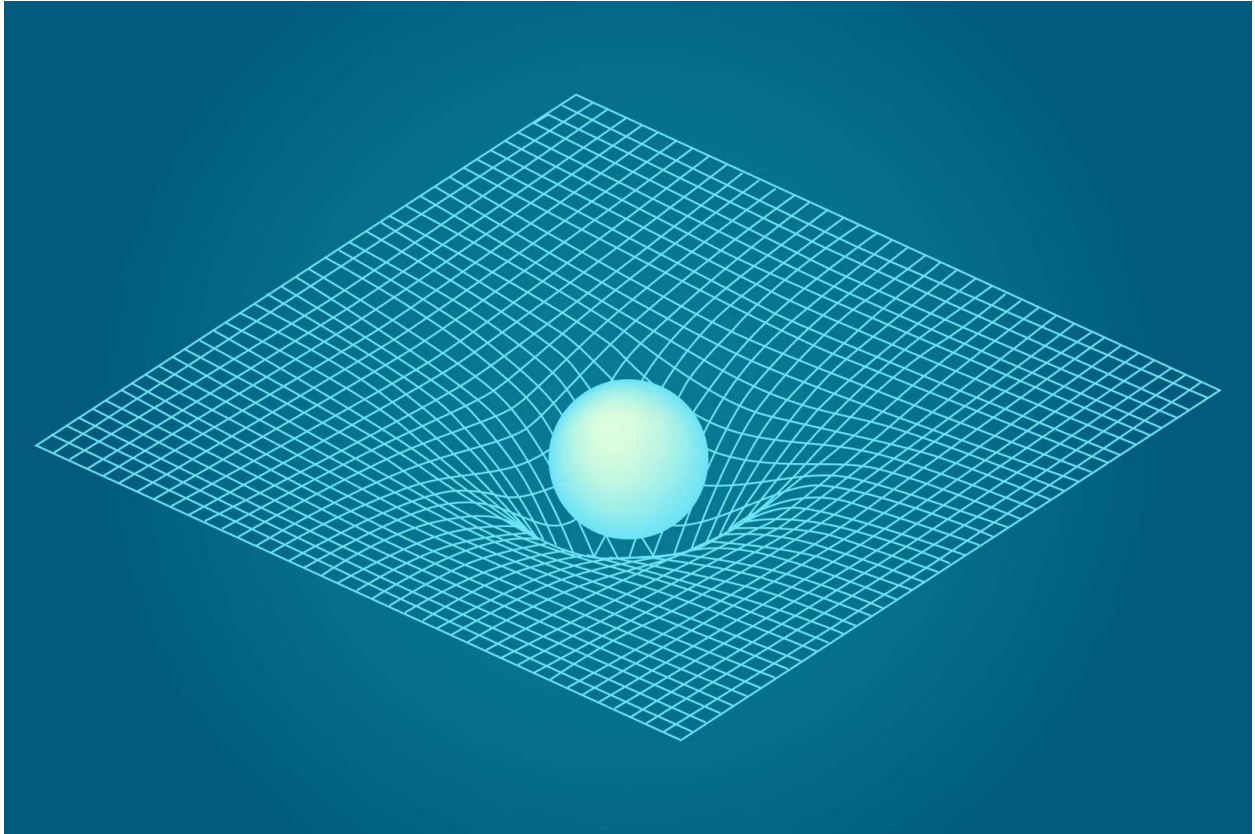
Responsibility without limits

In the 20th century, Emmanuel Levinas introduced the concept of infinite responsibility, which argues that ethical duty toward others has no boundaries. He believed morality was an infinite obligation, requiring humans to respond to the needs of others endlessly.



Contemporary views

Infinity is no longer just a philosophical idea; it plays a key role in math and physics. It also helps shape theories in cosmology about the universe, and in quantum physics, where it reveals fundamental aspects of reality and the mind.



Quantum physics

Infinity appears in quantum mechanics, where probability waves stretch across infinite possibilities. The field of study suggests that particles can exist in multiple states simultaneously, which makes infinity a crucial part of physics at the smallest known levels of reality.



Cosmology

Modern cosmology debates whether space is infinite. Some theories suggest an endlessly expanding universe, while others propose cycles wherein the universe expands and contracts without end.



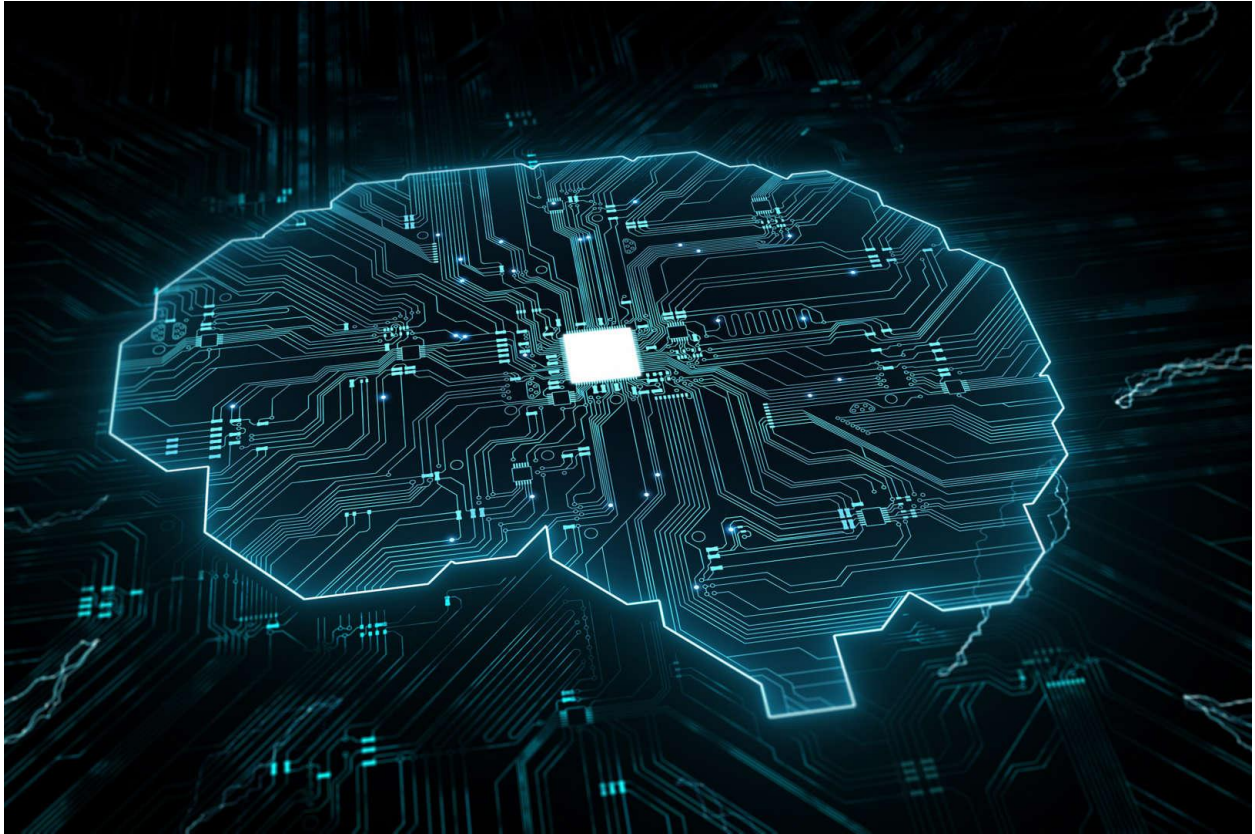
The multiverse hypothesis

Some physicists have even proposed a multiverse, suggesting that there are an infinite number of universes, each with different physical laws. If true, this would mean that infinite variations of reality exist, which makes our own universe just one of an endless number of possibilities.



Black holes

Black holes stretch physics to its limits. Their centers contain singularities, where density and gravity reach infinity and traditional equations become meaningless. These regions challenge our understanding of space, time, and the fundamental nature of reality.



AI and infinity

Artificial intelligence operates on vast amounts of data, which has led some to wonder if it could eventually process infinite knowledge. But questions still remain about whether computational power can truly break past human-imposed limits or if infinity is beyond even AI's grasp.

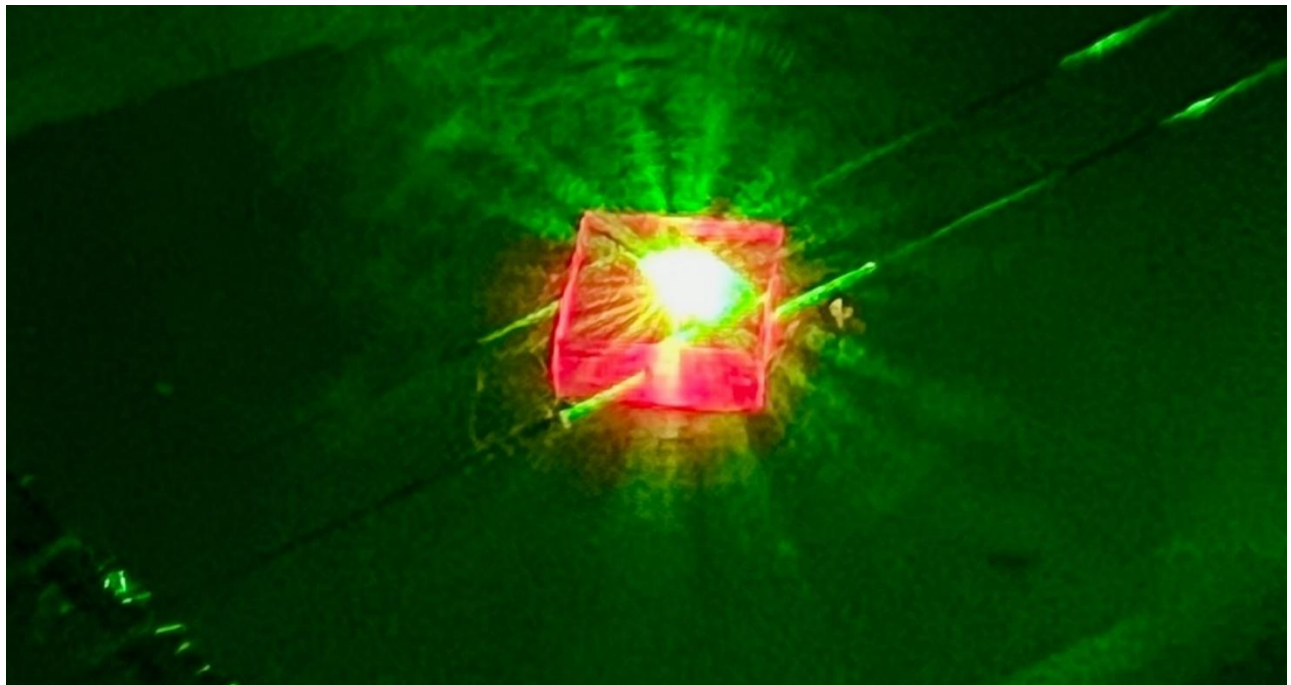
The infinite journey of human curiosity

The quest to understand infinity is itself infinite. Each new discovery opens more questions and ensures that humanity's exploration of the boundless never truly ends. Whether in philosophy, science, or art, infinity continues to challenge and expand the limits of thought.

Scientists unveil new type of 'time crystal' that defies our traditional understanding of time and motion

News By [Alan Bradley](#) published March 26, 2025

The latest time crystal innovation may expand the known boundaries of quantum mechanics.



The latest time crystal innovation may expand the known boundaries of quantum mechanics. (Image credit: WashU)

Physicists have created a new [type of time crystal](#) that may help confirm some fundamental theories about quantum interactions.

A standard time crystal is a new [phase of matter](#) that features perpetual motion without expending energy. According to Chong Zu, an assistant professor of physics at Washington University in St. Louis and one of the team's lead researchers, a time crystal resembles a traditional crystal.

However, unlike a traditional crystal, which repeats a pattern across the physical dimension of space, a time crystal repeats a pattern of motion, rearranging its atoms in the same way over time, Zu said. This causes the time crystal to vibrate at a set frequency.

A time crystal is theoretically capable of cycling through the same pattern infinitely without requiring any additional power — like a watch that never needs to be wound. The reality, however, is that time crystals are incredibly fragile and thus succumb to environmental pressures fairly easily.

Although time crystals have been around since 2016, a team has achieved something unprecedented: They've created a novel type of time crystal called a time quasicrystal. A [quasicrystal](#) is a solid that, like a regular crystal, has atoms arranged in a specific, nonrandom way, but without a repeating pattern.

This means that, unlike a standard time crystal that repeats the same pattern over and over, a time quasicrystal never repeats the way it arranges its atoms. Because there's no repetition, the crystal vibrates at different frequencies. As the researchers state in their findings, published in the journal [Physical Review X](#), time quasicrystals "are ordered but apparently not periodic."

How to build a quasicrystal

To create these new time quasicrystals, the researchers started with a millimeter-sized piece of diamond. Then, they created spaces inside the diamond's structure by bombarding it with powerful beams of nitrogen. The nitrogen displaced carbon atoms within the diamond's interior, leaving behind empty atomic chambers.

Nature abhors a vacuum, so electrons quickly flowed into these empty spaces and immediately began to interact with neighboring particles on a [quantum level](#). Each time quasicrystal represents a network of more than a million of these empty spaces inside the diamond, though each measures just one micrometer (one-millionth of a meter).

"We used microwave pulses to start the rhythms in the time quasicrystals," [Bingtian Ye](#), a researcher at MIT and a co-author of the paper, said in a [statement](#). "The microwaves help create order in time."

Potential applications

One of the most important outcomes of the team's research is that it confirms some basic theories of quantum mechanics, according to Zu. However, time quasicrystals may have practical applications in fields such as precision timekeeping, [quantum computing](#), and quantum sensor technology.

For sensors, the crystal's fragility and sensitivity are actually a boon; because they're so sensitive to environmental factors like magnetism, they can be used to create extremely precise sensors.

For quantum computing, the material's potential perpetual motion quality is the key.

"They could store quantum memory over long periods of time, essentially like a quantum analog of RAM," Zu said. "We're a long way from that sort of technology, but creating a time quasicrystal is a crucial first step."

Otherworldly 'time crystal' made inside Google quantum computer could change physics forever

News By [Ben Turner](#) published September 14, 2021



The crystal is able to forever cycle between states without losing energy.

The time crystal was created inside Google's Sycamore chip, which is kept cool inside their quantum cryostat. (Image credit: Eric Lucero/Google, Inc.)

Researchers working in partnership with Google may have just used the tech giant's quantum computer to create a completely new [phase of matter](#) — a time crystal. With the ability to forever cycle between two states without ever losing energy, time crystals dodge one of the most important laws of physics — the [second law of thermodynamics](#), which states that the disorder, or entropy, of an isolated system must always increase. These bizarre time crystals remain stable, resisting any dissolution into randomness, despite existing in a constant state of flux. According to a research article posted July 28 to the preprint database [arXiv](#), scientists were able to create the time crystal for roughly 100 seconds using qubits (quantum computing's version of the traditional computer bit) inside the core of Google's Sycamore quantum processor.

The existence of this weird new matter phase, and the entirely new realm of physical behaviors it reveals, is incredibly exciting to physicists, especially as time crystals were only first predicted to exist just nine years ago.

"This was a big surprise," Curt von Keyserlingk, a physicist at the University of Birmingham in the U.K. who was not involved in the study, told Live Science. "If you asked someone 30, 20 or maybe even 10 years ago, they would not have expected this."

Time crystals are fascinating objects to physicists because they essentially sidestep the second law of thermodynamics, one of the most ironclad laws in physics. It states that entropy (a rough analog for the amount of disorder in a system) always increases. If you want to make something more ordered, you need to put more energy into it.

This tendency for disorder to grow explains a lot of things, such as why it's easier to stir ingredients into a mixture than it is to separate them out again, or why headphone cords get so tangled in pants' pockets. It also sets the arrow of time, with the past universe always more ordered than the present; watching a video in reverse, for instance, is likely to look strange to you primarily because you're witnessing the counterintuitive reversal of this entropic flow.



The second law of thermodynamics says that all systems evolve toward a state of more disorder, where energy is shared out evenly across the system. (Image credit: Universal History Archive/Universal Images Group via Getty Images)

Time crystals don't follow this rule. Instead of slowly approaching thermal equilibrium — "thermalizing" so that their energy or temperature is equally distributed throughout their surroundings, they get stuck between two energy states above that equilibrium state, cycling back and forth between them indefinitely.

To explain how deeply unusual this behavior is, von Keyserlingk said to picture a sealed box filled with coins before being shaken a million times. As the coins ricochet from, and bounce around, each other, they "become more and more chaotic, exploring all of the sorts of configurations that they can explore" until the shaking stops, and the box is opened to reveal the coins in a random configuration, with roughly half of the coins facing up and half facing down. We can expect to see this random, half-up, half-down endpoint regardless of the way we first arranged the coins in the box.

Inside the "box" of Google's Sycamore, we can view the quantum processor's qubits much like we would our coins. In the same way that the coins can be either heads or tails, qubits can be either a 1 or a 0 — the two possible positions in a two-state system — or a weird mix of the probabilities of both states called a superposition. What's weird about time crystals, von Keyserlingk says, is that no amount of shaking, or zapping from one state to another, can move the time crystal's qubits into the lowest energy state, which is a random configuration; they can only flip it from its starting state to its second state, then back again.

"It just sort of flip-flops," von Keyserlingk said. "It doesn't end up looking random, it just gets jammed stuck. It's like it remembers what it looked like initially, and it repeats that pattern over time."

In this sense, a time crystal is like a pendulum that never stops swinging.

"Even if you totally physically isolate a pendulum from the universe, so there's no friction and no air resistance, it will eventually stop. And that's because of the second law of thermodynamics," Achilleas Lazarides, a physicist at the University of Loughborough in the U.K. who was among the scientists to first discover the theoretical possibility of the new phase in 2015, told Live Science. "Energy starts out concentrated in the pendulum's center of mass, but there's all of these internal degrees of freedom — like the ways the [atoms](#) can vibrate inside the rod — that it will eventually be transferred into."

In fact, there's no way for a large-scale object to behave like a time crystal without sounding absurd, because the only rules that enable time crystals to exist are the spooky and surreal rules that govern the world of the very small — [quantum mechanics](#).

In the quantum world, objects behave both like point particles and little waves at the same time, with the magnitude of these waves in any given region of space representing the probability of finding a particle at that location. But randomness (such as random defects in a crystal's structure or a programmed randomness in the interaction strengths between qubits) can cause a particle's probability wave to cancel itself out everywhere apart from one very small region. Rooted in place, unable to move, change states or thermalize with its surroundings, the particle becomes localized.

The researchers used this localization process as the foundation of their experiment. Using 20 strips of superconducting [aluminum](#) for their qubits, the scientists programmed each one into one of two possible states. Then, by blasting a microwave beam over the strips, they were able to drive their qubits to flip states; the researchers repeated the experiment for tens of thousands of runs and stopped at different points to record the states their qubits were in. What they found was that their collection of qubits was flipping back and forth between only two configurations, and the qubits weren't absorbing heat from the microwave beam either — they had made a time crystal.

They also saw a key clue that their time crystal was a phase of matter. For something to be considered a phase, it usually has to be very stable in the face of fluctuations. Solids will not melt if the [temperatures](#) around them vary slightly; neither will slight fluctuations cause liquids to evaporate or freeze suddenly. In the same way, if the microwave beam used to flip the qubits between states was adjusted to be close to but slightly off from the exact 180 degrees needed for a perfect flip, the qubits still nonetheless flipped to the other state. "It's not the case that if you're not exactly at the 180 degrees you will scramble them," Lazarides said. "It [the time crystal] magically will always tip a bit in, even if you're making slight mistakes."

Another hallmark of moving from one phase to another is the breaking of physical symmetries, the idea that the laws of physics are the same for an object at any point in time or space. As a liquid, the molecules in water follow the same physical laws at every point in space and in every direction, but cool water down enough so that it transforms into ice and its molecules will pick regular points along a crystal structure — or lattice — to arrange themselves across. Suddenly, the water molecules have preferred points in space to occupy, and they leave the other points empty — the spatial symmetry of the water has been spontaneously broken.

In much the same way that ice becomes a crystal in space by breaking with spatial symmetry, time crystals become crystals in time by breaking with time symmetry. At first, before their transformation into the time crystal phase, the row of qubits will experience a continuous symmetry between all moments in time. But the periodic cycle of the microwave beam chops the constant conditions experienced by the qubits down into discrete packets (making the symmetry imposed by the beam a discrete time-translation symmetry). Then, by flipping back and forth at twice the period of the wavelength of the beam, the qubits break with the discrete time-translation symmetry imposed by the laser. They are the first objects we know of that are able to do this.

All of this weirdness makes time crystals rich in new physics, and the control that Sycamore provides researchers beyond other experimental setups could make it an ideal platform for further investigation. That's not to say it cannot be improved, however. Like all quantum systems, Google's quantum computer needs to be perfectly isolated from its environment to prevent its qubits from undergoing a process called decoherence, which eventually breaks down the quantum localization effects, destroying the time crystal. The researchers are working on ways to better isolate their processor and mitigate the impact of decoherence, but it's unlikely they will eliminate the effect for good.

Despite this, Google's experiment is likely to remain the best way to study time crystals for the foreseeable future. Though numerous other projects have succeeded in making what convincingly appear to be time crystals in other ways — with diamonds, helium-3 superfluids, quasiparticles called magnons and with [Bose-Einstein condensates](#) — for the most part the crystals produced in these setups dissipate too quickly for detailed study. The theoretical newness of the crystals is in some ways a double-edged sword, as physicists currently struggle to find clear applications for them, although von Keyserlingk has suggested that they could be used as highly accurate sensors. Other proposals include using the crystals for better memory storage or for developing quantum computers with even faster processing power.

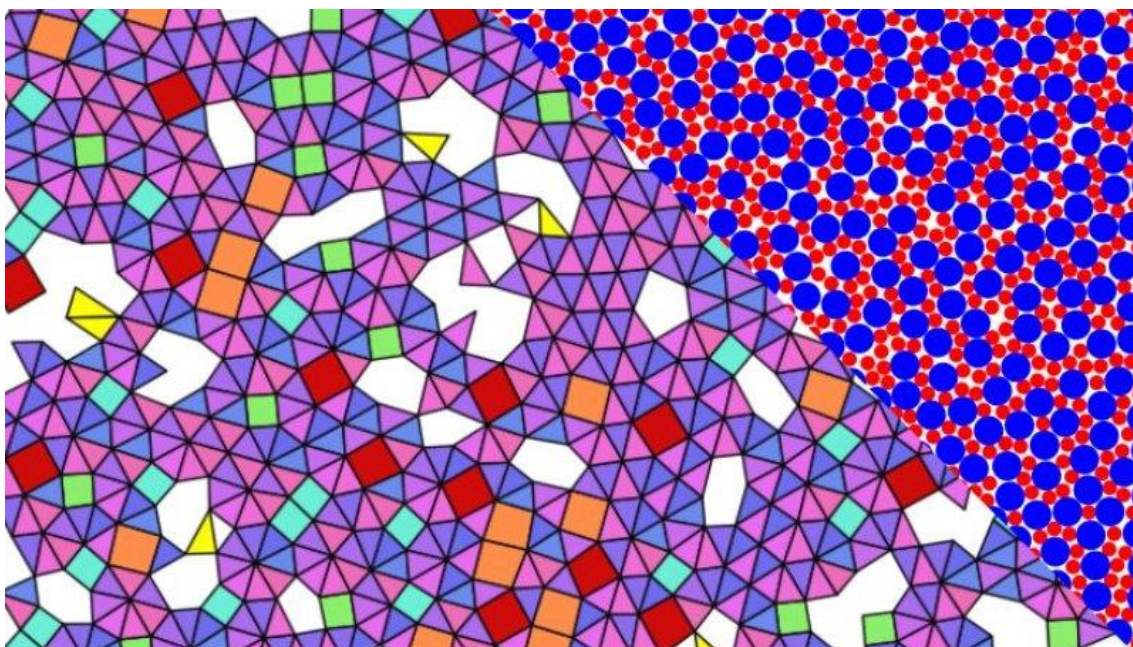
But in another sense, the greatest application of time crystals may already be here: They allow scientists to probe the boundaries of quantum mechanics.

"It allows you to not just study what shows up in nature, but to actually design it and look at what quantum mechanics lets you do and doesn't let you do," Lazarides said. "If you don't find something in nature then it doesn't mean it can't exist — we just created one of those things."

Scientists just made the largest quasicrystal ever — because one of them bet it couldn't be done

News By [Ben Turner](#) published July 21, 2023

The quasicrystal, a type of non-repeating crystal once deemed impossible, was made by jiggling thousands of metal balls in a tray for over a week.



An image of the computer simulation used to create the new quasicrystal. (Image credit: Plati et al., arXiv, 2023)

By jiggling thousands of metal beads in a tray for a week, researchers have created the largest-ever quasicrystal — a structure that scientists previously considered impossible.

First represented in the irregular, non-repeating tile patterns of early Islamic art, quasicrystals are crystals whose atoms fit into an ordered arrangement and yet, [fascinatingly, never repeat](#). They are crystals, yet they stubbornly break the rules of symmetry once used to divide traditional crystals from more chaotically structured solids. First theorized in 1981 and discovered in 1982, the once-controversial structures got the scientist who found them booted from his lab for defending his discovery — before later earning him the [2011 Nobel Prize in chemistry](#).

Now, scientists have created the biggest-ever quasicrystal from similarly contentious circumstances — as a consequence of a bet made between the lead researcher and a colleague about whether the experiment would work. The researchers published their findings July 4 on the preprint server [arXiv](#); the paper has not been peer-reviewed yet.

Since their discovery, hundreds of quasicrystals have been made in labs, and some have even been discovered in nature. Yet they are all fairly small and made from particles between micrometer and nanometer scales — or between 0.001% and 1% of a hair's width. The scientists wanted to see if they could make quasicrystals that were thousands of times bigger.

To investigate how big the particles inside a quasicrystal could feasibly get, the researchers ran computer simulations to find the best types of particles to form a large quasicrystal. Their results indicated that two particles should be used: one 2.4 millimeters (0.09 inch) in diameter and one with a diameter of 1.2 mm (0.047 inch).

After placing roughly 4,000 steel spheres of both sizes into a shallow container, the researchers set the spheres to jiggle and jostle at a rate of 120 times per second for a week and filmed the process as it occurred. After reviewing their experiment, the researchers wrote in their paper, "an interesting picture seems to emerge."

The spheres had arranged themselves into the tiled, non-repeating structure of a quasicrystal composed of three basic parts: large spheres in a square with either one or four smaller spheres plopped in the middle, and large spheres forming triangles with smaller spheres in their centers.

Most of the practical applications for quasicrystals are still a long way off, but their unique properties could allow them to shield objects from heat, reinforce steel and [repair broken bones](#). Further research into this new crystal and its similarities to other quasicrystals could bring these possibilities closer

Physicists link two time crystals in seemingly impossible experiment

News By [Paul Sutter](#) published June 14, 2022

New time crystal achievement could help bridge classical and quantum physics.



In

2012 it was physicist Frank Wilczek who proposed the idea of a time crystal. (Image credit: Chuanchai Pundej/EyeEm via Getty Images)

Physicists have created a system of two connected time crystals, which are strange quantum systems that are stuck in an endless loop to which the normal laws of thermodynamics do not apply. By connecting two time crystals together, the physicists hope to use the technology to eventually build a new kind of quantum computer.

"It is a rare privilege to explore a completely novel phase of matter," Samuli Autti, the lead scientist on the project from Lancaster University in the United Kingdom, told Live Science in an email.

From crystal to time crystal

We encounter normal crystals all the time in everyday life, from the ice in a cocktail to the diamonds in jewelry. While crystals are pretty, to a physicist they represent a breakdown of the normal symmetries of nature.

The laws of physics are symmetric through space. That means that the fundamental equations of [gravity](#) or [electromagnetism](#) or [quantum mechanics](#) apply equally throughout

the entirety of the volume of the [universe](#). They also work in any direction. So, a laboratory experiment that is rotated 90 degrees should produce the same results (all else being equal, of course).

But in a crystal, this gorgeous symmetry gets broken. The molecules of a crystal arrange themselves in a preferred direction, creating a repeating spatial structure. In the jargon of physicists, a crystal is a perfect example of "spontaneous symmetry breaking" — the fundamental laws of physics remain symmetric, but the arrangement of the molecules is not.

In 2012, physicist Frank Wilczek, at the Massachusetts Institute of Technology, noticed that the laws of physics also have a time symmetry. That means any experiment repeated at a later [time](#) should produce the same result. Wilczek made an analogy to normal crystals, but in the dimension of time, dubbing this spontaneous symmetry breaking through time a time crystal. A few years later, physicists were able to finally build one.

Related: 'X particle' from the dawn of time detected inside the Large Hadron Collider

Quantum secrets

"A time crystal keeps moving and repeats itself periodically in time in the absence of external encouragement," said Autti. This is possible because the time crystal is in its lowest energy state. The basic rules of quantum mechanics prevent the motion from becoming completely still, and so the time crystal remains "stuck" in its never-ending cycle.

"This means they are perpetual motion machines, and therefore impossible," remarked Autti.

The [laws of thermodynamics](#) suggest that systems in equilibrium tend toward more entropy, or disorder — a coffee cup sitting out will always cool, a pendulum will eventually stop swinging, and ball rolling on the ground eventually comes to rest. But a time crystal defies that, or simply ignores it, because the rules of thermodynamics don't seem to apply to it. Instead, time crystals are subject to quantum mechanics, the rules that govern the zoo of subatomic particles.

"In quantum physics, a perpetual motion machine is fine as long as we keep our eyes closed, and it must only start slowing down if we observe the motion," Autti said, referring to the fact that the exotic quantum mechanical states required for time crystals cannot keep operating once they interact with their environment (for example, if we observe them).

This implies that physicists can't directly observe time crystals. The moment they try to watch one, the quantum rules that allow them to exist break down, and the time crystal grinds to a halt. And that concept extends beyond observation: Any strong enough interaction with the external environment that breaks down the quantum state of the time crystal will make it stop being a time crystal.

This is where Autti's team came in, trying to find a way to interact with a quantum time crystal through classical observations. At the tiniest scale, quantum physics reigns. But bugs and cats and planets and black holes are better described by the deterministic rules of classical mechanics.

"The continuum from quantum physics to classical physics remains poorly understood. How one becomes the other is one of the outstanding mysteries of modern physics. Time crystals span a part of the interface between the two worlds. Perhaps we can learn how to remove the interface by studying time crystals in detail," said Autti.

Magical magnons

In the new study, Autti and his team used "magnons" to build their time crystal. Magnons are "quasiparticles," which emerge in the collective state of a group of [atoms](#). In this case, the team of physicists took helium-3 — a helium atom with two protons but only one neutron — and cooled it to within a ten-thousandth of a degree above absolute zero. At that temperature, the helium-3 transformed into a Bose-Einstein condensate, where all the atoms share a common quantum state and work in concert with each other. In that condensate, all the spins of the electrons in the helium-3 linked up and worked together, generating waves of magnetic energy, the magnons. These waves sloshed back and forth forever, making them a time crystal.

Autti's team took two groups of magnons, each one operating as its own time crystal, and brought them close enough to influence each other. The combined system of magnons acted as one time crystal with two different states.

Autti's team hopes that their experiments can clarify the relationship between quantum and classical physics. Their goal is to build time crystals that interact with their environments without the quantum states disintegrating, allowing the time crystal to keep running while it is used for something else. It wouldn't mean free energy — the motion associated with a time crystal doesn't have kinetic energy in the usual sense, but it could be used for quantum computing.

Having two states is important, because that is the basis for computation. In classical computer systems, the basic unit of information is a bit, which can take either a 0 or 1 state, while in quantum computing, each "qubit" can be in more than one place at the same time, allowing for much more computing power.

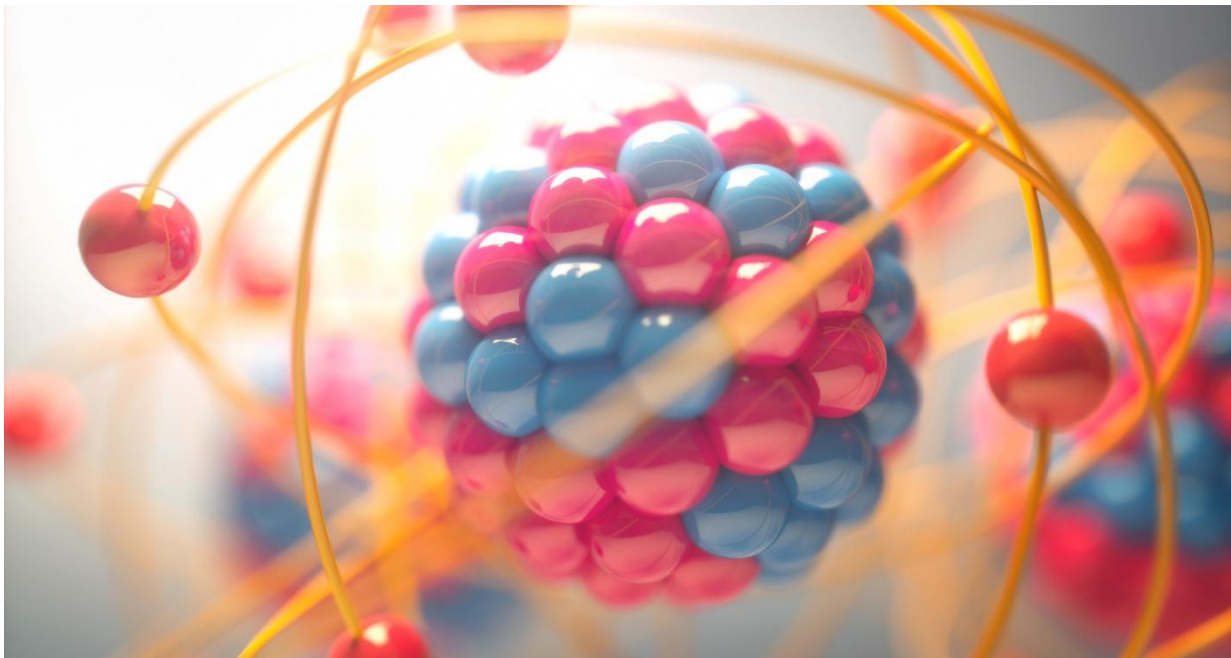
"This could mean that time crystals can be used as a building block for quantum devices that work also outside the laboratory. In such a venture the two-level system we have now created would be a basic building block," Autti said.

This work is currently very far away from a working quantum computer, but it does open up interesting avenues of research. If scientists can manipulate the two-time-crystal system without destroying its quantum states, they could potentially build larger systems of time crystals that serve as true computational devices.

Scientists create weird 'time crystal' from atoms inflated to be hundreds of times bigger than normal

News By [Ben Turner](#) published July 11, 2024

By blowing atoms up to several hundred times their size, researchers have been able to make another type of oddly-behaving time crystal.



A colorful image of an atom's nucleus. (Image credit: Getty Images)

Physicists have blown up atoms to hundreds of times their usual size to create a spectacular version of exotic matter that was once thought to be impossible.

The strange matter phase, known as a time crystal, was created by firing lasers at rubidium atoms until they ballooned into an excited form.

By doing so, the researchers say that they have opened a new avenue for exploring the properties of the mysterious crystals, which cycle periodically between two states seemingly without end, moving forever and never losing any energy.

The new technique, which was described July 2 in the journal [Nature Physics](#), could also help scientists to build better quantum computers.

"We have created a new system here that provides a powerful platform for deepening our understanding of the time crystal phenomenon in a way that comes very close to Frank

Wilczek's original idea," co-author [Thomas Pohl](#), a physicist at the University of Vienna, [said in a statement](#).

First proposed in 2012 by the Nobel-prize-winning physicist Wilczek, time crystals are groups of particles that repeat in time, much like other crystals (such as table salt or diamonds) repeat in space.

This is exciting to physicists. Usually the laws of physics, which are symmetrical across space and ([in most cases](#)) time, creating outcomes that are the same regardless of their direction in space and time.

But crystals break this symmetry, arranging themselves in a preferred spatial direction. This means that, even if physical laws are still symmetrical, they create different outcomes depending on the direction they act upon crystals.

In the same way that crystals break symmetry in space, time crystals break them in time. They exist in the lowest possible energy permitted by quantum mechanics, and oscillate between two states without slowing down.

These remarkable properties have led to many claims that time crystals are perpetual motion machines that violate the second law of thermodynamics, but [this isn't the case](#). The crystals, which are driven by lasers, simply cannot lose or gain energy — all the laser light hitting them does is cause them to repeat their two-step shuffle. This means that, like many systems containing only a handful of atoms, the second law does not apply to them. A number of time crystals have been made since Wilczek's proposal, each offering their own unique windows into this bizarre phase of matter. To build their time crystal, the researchers behind the new study turned to rubidium atoms excited into what are known as Rydberg states.

By firing laser light at a glass container filled with rubidium atoms, the physicists pumped the gas with tons of excess energy. The laser light excited the electrons found within the atoms, causing the spaces between their atomic nuclei and the electrons' outer shells to balloon to hundreds of times their usual size. This made something very interesting happen.

"If the atoms in our glass container are prepared in such Rydberg states and their diameter becomes huge, then the forces between these atoms also become very large," Pohl said. "And that in turn changes the way they interact with the laser. If you choose laser light in such a way that it can excite two different Rydberg states in each atom at the same time, then a feedback loop is generated that causes spontaneous oscillations between the two atomic states. This in turn also leads to oscillating light absorption."

In other words, a time crystal had appeared within the glass box.

"This is actually a static experiment in which no specific rhythm is imposed on the system," Pohl added. "The interactions between light and atoms are always the same, the laser beam has a constant intensity. But surprisingly, it turned out that the intensity that arrives at the other end of the glass cell begins to oscillate in highly regular patterns."

Now that they've created their new type of time crystal, the researchers will continue to experiment on it and test it for further applications. They have suggested that it could be used to create new, highly sensitive sensors, alongside helping scientists to better understand quantum synchronization — a phenomenon in which multiple quantum systems can be made to act in phase, that will aid in the development of better quantum computers.

'Quantum time flip' makes light move simultaneously forward and backward in time

News By [Ben Turner](#) published December 7, 2022

The time-flipped photon can't be used to restage "Back to the Future," but it could help us figure out some of the universe's most mysterious phenomena.



The mixed time directions of the photon could help physicists probe inside black holes. (Image credit: Shutterstock)

For the first time, physicists have made light appear to move simultaneously forward and backward in time. The new technique could help scientists improve quantum computing and understand quantum gravity.

By splitting a photon, or packet of light, using a special optical crystal, two independent teams of physicists have achieved what they describe as a 'quantum time flip', in which a photon exists in both forward and backward time states.

The effect results from the convergence of two strange principles of [quantum mechanics](#), the counterintuitive rules that govern the behavior of the very small. The first principle, quantum superposition, enables minuscule particles to exist in many different states, or different versions of themselves, at once, until they are observed. The second — charge, parity and time-reversal (CPT) symmetry — states that any system containing particles will obey the same physical laws even if the particles' charges, spatial coordinates and movements through time are flipped as if through a mirror.

By combining these two principles, the physicists produced a photon that appeared to simultaneously travel along and against the arrow of time. They published the results of their twin experiments [Oct. 31](#) and [Nov. 2](#) on the preprint server arXiv, meaning the findings have yet to be peer-reviewed.

"The concept of the arrow of time is giving a word to the apparent unidirectionality of time that we observe in the macroscopic world we inhabit," [Teodor Strömberg](#), a physicist at the University of Vienna who was first author on one of the papers, told Live Science. "This is actually in tension with many of the fundamental laws of physics, which by and large are time symmetric, and which therefore do not have a preferred time direction."

The [second law of thermodynamics](#) states that the entropy of a system, a rough analogue of its disorder, must increase. Known as the "arrow of time," entropy is one of the few quantities in physics that sets time to go in a particular direction.

This tendency for disorder to grow in the universe explains why it's easier to mix ingredients than to separate them. It's also through this growing disorder that entropy is wedded so intimately to our sense of time. A famous scene in Kurt Vonnegut's novel "Slaughterhouse-Five" demonstrates how differently entropy makes one direction of time look to the other by playing World War II in reverse: Bullets are sucked from wounded men; fires are shrunk, gathered into bombs, stacked in neat rows, and separated into composite minerals; and the reversed arrow of time undoes the disorder and devastation of war.

However, as entropy is primarily a statistical concept, it doesn't apply to single subatomic particles. In fact, in every particle interaction scientists have observed so far — including the up to 1 billion interactions per second that take place inside the world's largest atom smasher, the Large Hadron Collider — CPT symmetry is upheld. So particles seeming to move forward in time are indistinguishable from those in a mirrored system of antiparticles moving backward in time. (Antimatter was created with matter during the Big Bang and doesn't actually move backward in time; it just behaves as if it is following an opposite arrow of time to normal matter.)

The other factor at play in the new experiments is superposition. The most famous demonstration of quantum superposition is Schrödinger's cat, a thought experiment in which a cat is placed inside a sealed box with a vial of poison whose release is triggered by the radioactive decay of an alpha particle. Radioactive decay is a quantum mechanical process that occurs at random, so it is initially impossible to know what happened to the cat, which is in a superposition of states, simultaneously dead and alive, until the box is opened and the outcome observed.

This superposition of states enables a particle to exist in both forward and backward time states at the same time, but witnessing this feat experimentally is tricky. To achieve it, both teams devised similar experiments to split a photon along a superposition of two separate paths through a crystal. The superposed photon moved on one path through the crystal as normal, but another path was configured to change the photon's polarization, or where it points in space, to move as if it were traveling backward in time.

After recombining the superposed photons by sending them through another crystal, the team measured the photon polarization across a number of repeated experiments. They found a quantum interference pattern, a pattern of light and dark stripes that could exist only if the photon had been split and was moving in both time directions.

"The superposition of processes we realized is more akin to an object spinning clockwise and counter-clockwise at the same time," Strömberg said. The researchers created their time-flipped photon out of intellectual curiosity, but follow-up experiments showed that time flips can be paired with reversible logic gates to enable simultaneous computation in either direction, thus opening the way for quantum processors with greatly enhanced processing power.

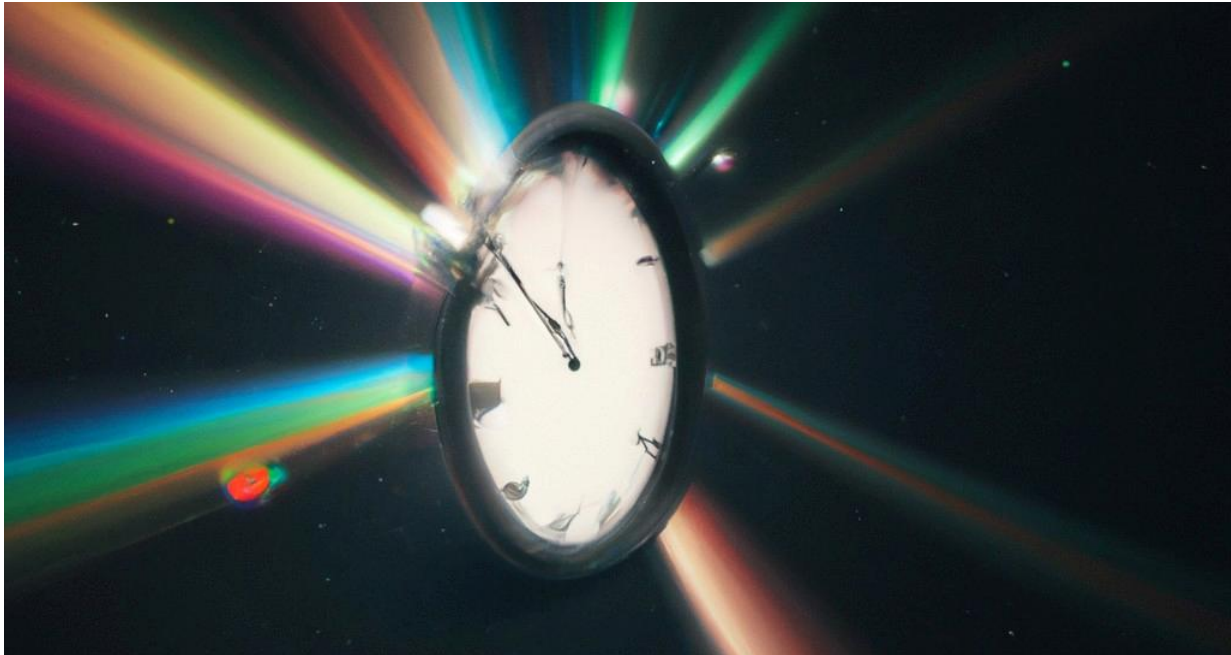
Theoretical possibilities also sprout from the work. A future theory of quantum gravity, which would unite general relativity and quantum mechanics, should include particles of mixed time orientations like the one in this experiment, and could enable the researchers to peer into some of the universe's most mysterious phenomena.

"A nice way to put it is to say that our experiment is a simulation of exotic scenarios where a photon might evolve forward and backward in time," [Giulio Chiribella](#), a physicist at the University of Oxford who was the lead author of the other paper, told Live Science. "What we do is an analogue to some experiments that simulate exotic physics, such as the physics of black holes or time travel."

Scientists create 'slits in time' in mind-bending physics experiment

News By [Anna Demming](#) published April 11, 2023

Researchers replicated the classic double slit experiment using lasers, but their slits are in time not space.



A new diffracton study sends lasers through 'slits in time' in a novel take on the classic double slit experiment. (Image credit: Thomas Angus, Imperial College London)

In a first, scientists have shown that they can send light through "slits" in time.

The new experiment is a twist on a 220-year-old demonstration, in which light shines through two slits in a screen to create a unique diffraction pattern across space, where the peaks and troughs of the light wave add up or cancel out. In the new experiment, researchers created a similar pattern in time, essentially changing the color of an ultrabrief laser pulse.

The findings pave the way for advances in analog computers that manipulate data imprinted on beams of light instead of digital bits - it might even make such computers "learn" from the data. They also deepen our understanding of the fundamental nature of light and its interactions with materials.

For the new study, described April 3 in the journal [Nature Physics](#), the researchers used indium tin oxide (ITO), the material found in most phone screens. Scientists already knew ITO could change from transparent to reflective in response to light, but the researchers

found it occurs much faster than previously thought, in less than 10 femtoseconds (10 millionths of a billionth of a second).

"This was a very big surprise and at the beginning it was something that we couldn't explain," study lead author [Riccardo Sapienza](#), a physicist at the Imperial College London, told Live Science. Eventually, the researchers figured out why the reaction happened so fast by scrutinizing the theory of how the electrons in ITO respond to incident light. "But it took us a long time to understand it."

Time swapping in for space

English scientist Thomas Young first demonstrated light's wave-like nature using the now classic "double-slit" experiment in 1801. As light shines on a screen with two slits, the waves change direction, so that waves fanning out from one slit overlap with the waves coming through the other. The peaks and troughs of these waves either add up or cancel out, creating bright and dark fringes, called an interference pattern.

In the new study, Sapienza and colleagues recreated such an interference pattern in time by shining a "pump" laser pulse at a screen coated in ITO. While the ITO was initially transparent, the light from the laser changed the properties of the electrons within the material so that the ITO reflected light like a mirror. A subsequent "probe" laser beam hitting the ITO screen would then see this temporary change in optical properties as a slit in time just a few hundred femtoseconds long. Using a second pump laser pulse made the material behave as if it had two slits in time, an analog of light passing through spatial double slits.

Whereas passing through conventional spatial slits causes light to change direction and fan out, as the light passed through these twin "time slits," it changed in frequency, which is inversely related to its wavelength. It is the wavelength of visible light that determines its color.

In the new experiment, the interference pattern showed up as fringes, or additional peaks in the frequency spectra, which are graphs of the measured light intensity at different frequencies. Just like altering the distance between spatial slits changes the resulting interference pattern, the lag between the time slits dictates the spacing of the interference fringes in the frequency spectra. And the number of fringes in these interference patterns that are visible before their amplitude decreases to the level of background noise reveals how quickly the ITO properties are changing; materials with slower responses yield fewer detectable interference fringes.

This isn't the first time that scientists have figured out how to manipulate light across time, rather than space. For instance, scientists at [Google say their quantum computer "Sycamore" created a time crystal](#), a new phase of matter that changes periodically in time, as opposed to atoms being arranged in a periodic pattern across space. [Andrea Alù](#), a physicist at The City University of New York who was not involved with these experiments but has done separate experiments that created reflections of light in time, described it as yet another "neat demonstration" of how time and space can be interchangeable..

"The most remarkable aspect of the experiment is that it demonstrates how we can switch the permittivity [which defines how much a material transmits or reflects light] of this material (ITO) very fast, and by a significant amount," Alù told Live Science via email. "This confirms that this material can be an ideal candidate for the demonstration of time reflections and time crystals."

The researchers hope to use these phenomena to create metamaterials, or structures designed to alter the path of light in specific and often sophisticated ways.

So far these metamaterials have been static, meaning changing how the metamaterial affects light's path requires using a whole new metamaterial structure — a new analog computer for each different type of calculation, for instance, Sapienza said.

"Now we have a material we can reconfigure, which means we can use it for more than one purpose," said Sapienza. He added that such technology could enable neuromorphic computing that mimics the brain.

JUNE 21, 2025

New theory proposes time has three dimensions, with space as a secondary effect

by Rod Boyce, [University of Alaska Fairbanks](#) edited by [Andrew Zinin](#)

Time, not space plus time, might be the single fundamental property in which all physical phenomena occur, according to a new theory by a University of Alaska Fairbanks scientist.

The theory also argues that time comes in three [dimensions](#) rather than just the single one we experience as continual forward progression. Space emerges as a secondary manifestation.

"These three time dimensions are the primary fabric of everything, like the canvas of a painting," said associate research professor Gunther Kletetschka at the UAF Geophysical Institute. "Space still exists with its three dimensions, but it's more like the paint on the canvas rather than the canvas itself."

Those thoughts are a marked difference from generally accepted physics, which holds that a single dimension of time plus the three dimensions of space constitute reality. This is known as spacetime, the concept developed more than a century ago that views time and space as one entity.

Kletetschka's mathematical formula of six total dimensions—of time and space combined—could bring scientists closer to finding the single unifying explanation of the universe.

Dimensions of time beyond our everyday forward progression are difficult to grasp. Theoretical physicists have proposed many variations.

Kletetschka's work, published April 21 in [Reports in Advances of Physical Science](#), adds to a long-running body of research by theoretical physicists on a subject outside of mainstream physics.

He writes that his [mathematical framework](#) for three-dimensional time improves on others' proposals by making testable reproductions of known particle masses and other physical properties.

"Earlier 3D time proposals were primarily mathematical constructs without these concrete experimental connections," he said. "My work transforms the concept from an interesting mathematical possibility into a physically testable theory with multiple independent verification channels."

The theory could be used to predict currently unknown particle properties and aid in pursuing the origin of mass—and, ultimately, helping solve one of the biggest questions in physics.

What is 3D time?

Three-dimensional time is a theory in which time, like space, has multiple independent directions—typically imagined as three axes of time motion, similar in concept to the spatial X, Y and Z axes.

Imagine you are walking down a straight path, moving forward and therefore experiencing time as we know it. Now imagine another path that crosses the first one, going sideways.

If you could step onto that sideways path and remain in the same moment of "regular time," you might find that things could be slightly different—perhaps a different version of the same day. Moving along this perpendicular second path could let you explore different outcomes of that day without going backward or forward in time as we know it.

The existence of those different outcomes is the second dimension of time. The means to transition from one outcome to another is the third dimension.

Kletetschka said his theory overcomes some of the problems with earlier three-dimensional time theories that are based on traditional physics.

Those earlier theories, for example, describe multiple time dimensions in which cause-and-effect relationships are potentially ambiguous. Kletetschka's theory ensures that causes still precede effects, even with multiple time dimensions, just in a more complex mathematical structure.

In three-dimensional time, the second and third dimensions are thought by some researchers, notably theoretical physicist Itzhak Bars of the University of Southern

California, to become apparent, or unfold, at levels of extreme energy such as during the early universe or in high-energy particle interactions.

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A grand unifier?

The pursuit of three-dimensional time theory is believed by Bars and other [theoretical physicists](#) to be an avenue for helping answer some big physics questions that have stumped scientists.

Kletetschka's approach might even help resolve the grandest of all unresolved physics challenges: unifying [quantum mechanics](#)—the behavior of particles at the smallest scales—and gravity into a single quantum theory of gravity.

A quantum theory of gravity could lead to, or become, a grand theory of the universe—the so-called "theory of everything." The elusive unifying theory would unite the four fundamental forces of nature—electromagnetism, strong nuclear force, weak nuclear force and gravity.

The standard model of particle physics unites the first three. Gravity is explained through Albert Einstein's general theory of relativity.

The two are incompatible, so physicists have been searching for that "theory of everything" to unite them. Finding the origin of particle masses is central in that pursuit.

Kletetschka believes his theory of three-dimensional time can help. His framework accurately reproduces the known masses of particles such as electrons, muons and quarks and also explains why these particles have these masses.

"The path to unification might require fundamentally reconsidering the nature of physical reality itself," he said. "This theory demonstrates how viewing time as three-dimensional can naturally resolve multiple physics puzzles through a single coherent mathematical framework."

More information: Gunther Kletetschka, Three-Dimensional Time: A Mathematical Framework for Fundamental Physics, *Reports in Advances of Physical Sciences* (2025). DOI: [10.1142/S2424942425500045](https://doi.org/10.1142/S2424942425500045)
Provided by [University of Alaska Fairbanks](#)

Space Might Be A Byproduct Of Three-Dimensional Time



What if time didn't just go in one direction, or even repeat in cycles, but had three dimensions under sufficiently extreme circumstances? - Image credit: Quality Stock Arts/Shutterstock.com© IFL Science

A new theory of the fabric of the universe has proposed that time has three dimensions. Moreover, this model leads to the conclusion that these three time dimensions are the true underlying feature of the universe, and the dimensions collectively known as space are just a byproduct, one might even say an offshoot. Currently this is just one of a great many proposals about the dimensions that make up the universe, with most other physicists yet to express a judgement as to its plausibility.

We experience time passing, irrespective of what we do, in a way we don't for the dimensions of space, and therefore intuitively consider it something quite different. So it was a shock when Einstein argued there are really four dimensions of a single quantity, which he named [spacetime](#).

The idea that time is just another dimension like length or height meets a lot of resistance from non-physicists for the same reason – it doesn't *feel* the same to us. However, Einstein's model works so well for explaining, and indeed [predicting](#), what we see that it has become part of physicists' standard toolkit.

Plenty of effort has gone into explaining why time only flows one way ([at least in our experience](#)), but some physicists have even greater ambitions, promoting more exotic hypotheses such as [string theory](#), where there are 11 dimensions, of which space and time are just four. The work of Dr Gunther Kletetschka of the University of Alaska Fairbanks is the latest multi-dimensional alternative, and not even the first to propose three time dimensions.

The idea of time being triplicate is not just a case of physicists' shower thoughts. Instead, Kletetschka argues, it is hinted at on scales from quantum phenomena to what we know of cosmological evolution. However, previous models of how these dimensions relate have produced apparent paradoxes, which Kletetschka says his work avoids.

Kletetschka claims that if we could move in all three dimensions of time, instead of just one, we could experience multiple versions of the same reality, like the multiverse idea science fiction writers [love to play with](#).

If you could move in the second time dimension you might encounter slightly different versions of the day you started in, becoming more different the further you go along that timeline. If you were not also traveling in familiar time, you'd experience these versions of the same moment without moving on, like Groundhog Day reduced to a second. Alternatively, you might move in two time dimensions at once, encountering successively slightly later versions of each reality. Meanwhile, the third time dimension provides the means to move from reality to another.

"Three time dimensions are the primary fabric of everything, like the canvas of a painting," Kletetschka said in a [statement](#). "Space still exists with its three dimensions, but it's more like the paint on the canvas rather than the canvas itself." Feel small already?

"Just as matter curves spacetime in General Relativity, here the paper proposes that what we perceive as mass and energy are manifestations of temporal curvature and dynamics," Kletetschka writes.

We only experience one dimension of time, Kletetschka writes, because the other two “become apparent only at extreme scales.”

Many existing exotic models of a higher dimensional universe have been criticized because they are so hard to explore experimentally. In some cases we have no idea how to test them at all; in others we do, but it requires building particle accelerators far more powerful than those we have today.

This is where Kletetschka says his idea stands out. “Earlier 3D time proposals were primarily mathematical constructs without these concrete experimental connections,” he said. “My work transforms the concept from an interesting mathematical possibility into a physically testable theory with multiple independent verification channels.”

The new theory requires certain subatomic particles to have specific masses. In the cases of those where these masses are known, including the top quark and the [electron](#), the values Kletetschka calculates match those that have been measured very precisely.

A much tougher test is whether Kletetschka can use his model to correctly predict the mass of particles we haven’t measured yet. He has predicted that two [neutrino types](#) have masses of 0.058 and 0.0086 eV, with 7 and 4 percent precision respectively. He also claims to be able to predict subtle differences in the speed of gravitational waves and of light, normally treated as equal.

“These signatures will be testable through next-generation collider experiments, gravitational wave observatories, and cosmological surveys in the 2025–2030 timeframe,” Kletetschka writes in his paper.

Some theories of time, particularly previous ones involving three dimensions, run into problems of cause and effect, which becomes a great deal more complicated if time is not a river sweeping us ever forwards. Kletetschka however, always has causes coming before consequences, a second great advantage for his version, along with testability.

If Kletetschka is right, his work will provide a major stepping stone to uniting [quantum mechanics and gravitational theory](#), which remains physicists’ holy grail.

Three-Dimensional Time: A Mathematical Framework for Fundamental Physics

Gunther Kletetschka

<https://doi.org/10.1142/S2424942425500045>

Abstract

This paper introduces a theoretical framework based on three-dimensional time, where the three temporal dimensions emerge from fundamental symmetry requirements. The necessity for exactly three temporal dimensions arises from observed quantum-classical-cosmological transitions that manifest at three distinct scales: Planck-scale quantum phenomena, interaction-scale processes, and cosmological evolution. These temporal scales directly generate three particle generations through eigenvalue equations of the temporal metric, naturally explaining both the number of generations and their mass hierarchy. The framework introduces a metric structure with three temporal and three spatial dimensions, preserving causality and unitarity while extending standard quantum mechanics and field theory. While earlier work explored three-dimensional time in Kaluza–Klein theory, this paper’s approach provides specific experimental predictions and a complete particle spectrum. This approach provides elegant solutions to long-standing problems in particle physics: the three-generation structure emerges naturally from temporal symmetries, weak interaction parity violation arises from geometric properties, and quantum gravity achieves finite corrections without ultraviolet divergences. The framework accurately reproduces known particle masses, including the top quark ($173.21 \pm 0.51 \text{ GeV}$, measured $173.2 \pm 0.9 \text{ GeV}$), muon ($105.6583745 \pm 0.0000024 \text{ MeV}$, measured $105.6583755 \pm 0.0000023 \text{ MeV}$), and electron ($0.5109989461 \pm 0.0000000031 \text{ MeV}$, measured $0.5109989461 \pm 0.0000000031 \text{ MeV}$). Building on this validation, the theory makes precise quantitative predictions, including neutrino masses ($\nu_3: 0.058 \pm 0.004 \text{ eV}$, $\nu_2: 0.0086 \pm 0.0003 \text{ eV}$), new resonances at $M_1 = 2.3 \pm 0.4 \text{ TeV}$ and $M_2 = 4.1 \pm 0.6 \text{ TeV}$, and gravitational wave speed modifications of $\Delta v/c = (1.5 \pm 0.3) \times 10^{-15}$. These signatures will be testable through next-generation collider experiments, gravitational wave observatories, and cosmological surveys in the 2025–2030 timeframe. Notably, General Relativity emerges as a natural limiting case when two temporal dimensions become negligible. The mathematical consistency and predictive power of this framework, combined with its ability to unify quantum and gravitational phenomena, suggest it deserves consideration as a fundamental theory of physics.

Keywords:

- Three-dimensional time
- quantum gravity

- unified field theory
- particle physics
- cosmology
- symmetry breaking
- gravitational waves

Abbreviations

CMB — Cosmic Microwave Background

CKM — Cabibbo-Kobayashi-Maskawa

CP — Charge Parity

DUNE — Deep Underground Neutrino Experiment

FCC-hh — Future Circular Collider-hadron hadron

HL-LHC — High-Luminosity Large Hadron Collider

ILC — International Linear Collider

LISA — Laser Interferometer Space Antenna

LIGO — Laser Interferometer Gravitational-wave Observatory

QFT — Quantum Field Theory

SNR — Signal-to-Noise Ratio

1. Introduction

The unification of quantum mechanics and gravity remains one of physics' most challenging problems.^{1,2} Despite significant theoretical advances, including string theory^{3,4} and loop quantum gravity,⁵ a complete reconciliation of quantum and gravitational phenomena remains elusive.⁶ Recent work by Flomenbom suggests that gravity may be understood through an imaginary mass field operating faster than light speed, providing another perspective on unification.⁷

The path to unification might require fundamentally reconsidering the nature of physical reality itself.

The three temporal dimensions in this framework correspond to distinct physical scales and phenomena (see Fig. 1). These orthogonal dimensions, intersecting at the origin of time, provide a geometric foundation for understanding fundamental physics:

Fig. 1. Three-dimensional time coordinate system showing orthogonal temporal dimensions intersecting at the "Origin of time" (potentially corresponding to the Big Bang). The quantum scale (t_1 , green) governs mass generation, yielding the observed particle generation mass ratios $m_1:m_2:m_3=1:4.5:21.0$. The interaction scale (t_2 , blue) mediates quantum effects and finite corrections. The cosmological

scale (t_3 , red) is associated with gravitational waves, with a measured strain amplitude $\Delta\sqrt{c}=1.5\times 10^{-15}$. This left-handed coordinate system naturally explains parity violation in weak interactions through the current $J_a=\Psi\gamma_a(1-\gamma_5)\Psi$. In the equation γ_5 represents the fifth gamma matrix, and "a" is a superscript in both J_a and γ_a , which is a Lorentz index that should run over spacetime coordinates (0,1,2,3).

The first temporal dimension (t_1) corresponds to quantum-scale phenomena, operating at the Planck time scale. This dimension governs quantum mechanical behavior and fundamental particle interactions.

The second temporal dimension (t_2) manifests at the interaction scale, mediating the interplay between quantum and classical phenomena. This dimension is crucial for understanding particle generations and weak interactions.

The third temporal dimension (t_3) operates at cosmological time scales, governing large-scale structure evolution and gravitational phenomena.

These three dimensions are not arbitrary but emerge naturally from fundamental symmetry requirements. Their distinct scales explain why we typically perceive only one temporal dimension in everyday experience, as the effects of t_2 and t_3 become apparent only at extreme scales. The interplay between these temporal dimensions provides a natural framework for understanding particle generations, weak interaction asymmetries, and the quantum-to-classical transition.

While traditional physics treats time as fundamentally different from space, this framework suggests that time might be the primary fabric of the universe, with mass and energy being manifestations of temporal structure. Just as matter curves spacetime in General Relativity, here the paper proposes that what we perceive as mass and energy are manifestations of temporal curvature and dynamics. This perspective inverts the conventional view: rather than matter existing in time, matter is a property of time itself. The three-dimensional temporal structure provides natural “degrees of freedom” that manifest as the observed properties of particles and fields. This philosophical reframing — viewing time as the fundamental substance of reality rather than as a background parameter — leads to surprising mathematical consistency and experimental predictions.

This paper presents a framework based on extending time to three dimensions, building upon earlier investigations of multiple time dimensions,^{8,9} including Chen’s work in Kaluza–Klein theory.¹⁰ While previous attempts faced causality and stability challenges,^{11,12} this approach resolves these issues through a specifically three-dimensional temporal structure. Unlike previous theoretical attempts at unification, no additional spatial dimensions, supersymmetric partners, or exotic mathematical structures are required. Key advances include maintained causality, automatic emergence of three generations, natural incorporation of weak interaction

asymmetry, and most importantly, explicit experimental predictions and a complete particle spectrum.

The proposed framework addresses long-standing problems in particle physics, including the origin of three generations,^{11,12} the nature of weak interaction parity violation,¹³ and the source of CP violation.¹⁴ Furthermore, it provides a natural framework for quantum gravity that avoids the usual ultraviolet divergences.^{15,16}

This paper's approach extends the standard metric structure to incorporate three temporal dimensions while maintaining causality and unitarity.¹⁷ This extension leads to a natural emergence of observed symmetries¹⁸ and provides clear experimental predictions.¹⁹

The remainder of this paper is organized as follows: Sec. 2 presents the mathematical foundation of the 3D time framework, including metric structure, field equations, and conservation laws. Section 3 develops the physical implications and presents specific testable predictions. Section 4 discusses theoretical advances, advantages over current theories, and proposed experimental tests. The paper concludes by outlining future research directions and summarizing the framework's significance for fundamental physics.

1.1. Analysis of alternative temporal dimensionality

While multiple time dimensions have been explored in theoretical physics, the choice of exactly three temporal dimensions is not arbitrary but mathematically and physically motivated.

The framework's reliance on three temporal dimensions emerges from both theoretical necessity and observational constraints. While two-dimensional time frameworks have been explored in theoretical physics, they prove fundamentally insufficient for describing the full spectrum of physical phenomena. Two-dimensional temporal structures cannot naturally accommodate three particle generations, fail to fully describe weak interaction asymmetries, and provide incomplete coupling between quantum and cosmological scales. Most critically, $2T$ frameworks cannot simultaneously resolve quantum gravity divergences while maintaining causality, and lack sufficient degrees of freedom to explain observed particle mass hierarchies.

Extending beyond three temporal dimensions creates even more significant challenges. Four-dimensional time frameworks and those of higher dimensionality introduce excessive degrees of freedom that would predict unobserved particles. These higher-dimensional structures suffer from inherent causality violations that cannot be resolved through standard mechanisms, generate unstable vacuum states, and produce coupling constant relationships that contradict experimental observations. Furthermore, such frameworks create inconsistencies with observed cosmological structure formation.

In contrast, the three-dimensional time framework uniquely satisfies both theoretical requirements and observational constraints. It naturally generates three particle generations with correct mass hierarchy relationships while maintaining a stable vacuum configuration. The framework preserves causality while providing complete coupling between quantum, classical, and cosmological phenomena. This mathematical consistency with observed symmetries,

combined with its predictive power, indicates that three temporal dimensions represent the unique solution that bridges quantum and gravitational physics without introducing extraneous complications or contradictions.

The framework's success in unifying seemingly disparate physical phenomena while maintaining mathematical consistency and experimental agreement suggests that three-dimensional time is not merely a mathematical construct but rather a fundamental aspect of physical reality. This precise dimensionality emerges as the unique solution that satisfies the complex web of theoretical constraints and observational evidence that characterize our universe.

2. Mathematical Foundation

2.1. Metric structure and basic properties

The fundamental postulate of this paper's framework is a six-dimensional manifold with three temporal and three spatial dimensions. The metric structure is given by

$$ds^2 = dt^2 + dt^2 + dt^2 - dx^2 - dy^2 - dz^2 \quad (1)$$

$$= d\tau^2 - d\Sigma^2 \quad (2)$$

where

$$\tau^2 = t^2 + t^2 + t^2 \text{ (temporal interval)}, \quad (3)$$

$$\Sigma^2 = x^2 + y^2 + z^2 \text{ (spatial interval)}. \quad (4)$$

This metric structure builds upon previous work in higher-dimensional theories,¹⁰ but extends the formalism to incorporate explicit physical observables and experimental signatures. The choice of metric signature $(+, +, +, -, -, -)$ is fundamental to the framework's consistency. This signature preserves rotational invariance in the three-dimensional time manifold, allowing proper temporal symmetries, while ensuring compatibility with observed quantum field behavior by maintaining positive energy conditions. It naturally reduces to standard Minkowski spacetime $(+, -, -, -)$ when two temporal dimensions become negligible, and maintains microcausality through proper light cone structure in all temporal projections.^{10,20}

The metric's structure guarantees quantum mechanical probability conservation and energy positivity, while allowing for the extended symmetries necessary for particle generation structure. Causality is preserved through specific interval conditions: $ds^2 > 0$ for timelike intervals, $ds^2 = 0$ for null intervals, and $ds^2 < 0$ for spacelike intervals.

2.2. Field equations

The generalized field equations take the form:

$$R_{ab}(T, x) = \kappa T_{ab}(T, x), \quad (5)$$

where R represents the temporal-spatial curvature tensor, T denotes the energy-momentum tensor, and κ is the coupling constant.

$$\kappa = 8\pi G/c^4. \quad (6)$$

This framework naturally contains General Relativity as a limiting case when two temporal dimensions become negligible ($t_2, t_3 \rightarrow 0$), yielding Einstein's field equations.^{20,21}

2.3. Wave function structure

The quantum mechanical description in 3D time is given by

$$\Psi(T, x) = \sum_{ijk} c_{ijk} \psi(x) \exp(i\omega_1 t_1 + i\omega_2 t_2 + i\omega_3 t_3) \quad (7)$$

with normalization

$$\int |\Psi|^2 dt_1 dt_2 dt_3 d^3x = 1. \quad (8)$$

The relationship between multi-temporal wave functions and quantum behavior was first explored by Chen¹⁰ in a Kaluza–Klein context, though this paper's framework develops different physical implications. The connection to standard Quantum Field Theory emerges naturally through field operators taking the extended form^{22,23}

$$\varphi(T, x) = \int d^3k [a_k \exp(-i\omega \cdot T + ik \cdot x) + a_k^\dagger \exp(i\omega \cdot T - ik \cdot x)], \quad (9)$$

where $\omega \cdot T = \omega_1 t_1 + \omega_2 t_2 + \omega_3 t_3$. Here a_k and $a_k^\dagger$ are the standard annihilation and creation operators respectively, with † denoting the Hermitian conjugate. The modified propagator structure

$$G(k, \omega) = [k^2 + \omega_1^2 + \omega_2^2 + \omega_3^2]^{-1} \quad (10)$$

reduces to the standard QFT propagator when $\omega_2, \omega_3 \rightarrow 0$. This ensures that conventional quantum field theory emerges in appropriate limits while maintaining the extended structure necessary for the framework's predictions.

2.4. Symmetry properties

The framework exhibits three fundamental symmetries: temporal rotations described by $SO(3, T)$, spatial rotations characterized by $SO(3, X)$, and a combined group structure $G = SO(3, T) \rtimes [SO(3, X) \times U(1)]$. These symmetries form the mathematical foundation for the physical predictions developed in subsequent sections.

2.5. Conservation laws

The extended conservation laws in three-dimensional time include:

$$\text{Energy-momentum: } \partial_\mu T_{ab} = 0, \quad (11)$$

where μ, a, b run over all coordinates (t_1, t_2, t_3, x, y, z) , ∂_μ is the covariant derivative, and T_{ab} is the energy-momentum tensor. The equation represents 36 coupled differential equations.

$$\text{Angular momentum: } \partial_\mu M_{abg} = 0, \quad (12)$$

where μ, a, b, g run over all coordinates (t_1, t_2, t_3, x, y, z) , ∂_μ is the covariant derivative, and M_{abg} is the angular momentum tensor, antisymmetric in its first two indices. The equation represents a set of 216 coupled differential equations ($6 \times 6 \times 6 \times 6$).

$$\text{Temporal charge: } \partial_\mu Q_{a_T} = 0. \quad (13)$$

where μ, a run over all coordinates (t_1, t_2, t_3, x, y, z) , ∂_μ is the covariant derivative, Q_{a_T} is the temporal charge tensor, and $_T$ denotes the temporal index. The equation represents 36 coupled

differential equations (6×6). The $_T$ index distinguishes this as specifically relating to temporal symmetries.

These conservation laws provide the fundamental constraints that govern the dynamics of the system in the extended temporal framework. The energy-momentum conservation accounts for flows in all temporal directions, while the angular momentum conservation includes rotations between different time dimensions. The temporal charge conservation reflects new symmetries unique to multi-temporal physics.

3. Physical Implications

3.1. Natural emergence of three generations

While previous approaches have considered spin as rotation in extra time dimensions,¹⁰ this work's framework naturally produces the observed particle spectrum through temporal symmetries. The temporal structure directly yields three generations through the eigenvalue equation:

$$(\partial^2/\partial t_1^2 + \partial^2/\partial t_2^2 + \partial^2/\partial t_3^2)\Psi_n = -m_n^2\Psi_n, (14)$$

where Ψ_n represents the particle wavefunction for generation n , and m_n is the mass of the n th generation.

This equation leads to a mass relation:

$$m_n = m_0 \exp(-\alpha n^\gamma), n=1,2,3, (15)$$

where m_0 is a reference mass, and α and γ are constants.

The theory predicts mass ratios:

$$m_1:m_2:m_3 = 1:(4.5):(21.0). (16)$$

The framework provides precise quantitative predictions across all fermion sectors. In the quark sector, this work predicts masses of $173.2 \pm 0.9 \text{ GeV}$ for the top quark, $1.27 \pm 0.02 \text{ GeV}$ for the charm quark, and $2.16 \pm 0.49 \text{ MeV}$ for the up quark. The lepton sector shows similar hierarchical structure, with masses of $1776.86 \pm 0.12 \text{ MeV}$ for the tau, $105.6583745 \pm 0.0000024 \text{ MeV}$ for the muon, and $0.5109989461 \pm 0.000000031 \text{ MeV}$ for the electron. For neutrinos, this work predicts masses of $0.058 \pm 0.004 \text{ eV}$ for ν_3 , $0.0086 \pm 0.0003 \text{ eV}$ for ν_2 , and $0.0023 \pm 0.0002 \text{ eV}$ for ν_1 , with mass ratios showing remarkable precision: $m_2/m_1 = 4.5 \pm 0.3$ and $m_3/m_1 = 21.0 \pm 1.5$.

These predictions are experimentally testable through multiple channels. The HL-LHC will achieve mass precision of $\delta m/m < 0.5\%$, while future colliders will improve this to $\delta m/m < 0.1\%$. Precision flavor physics experiments in the 2025–2030 timeline will provide additional verification of these mass relationships.^{24,25,26}

3.2. Weak interaction asymmetry

The three-dimensional temporal structure naturally explains parity violation through the current:

$$J_\alpha = \bar{\Psi} \gamma_\alpha (1 - \gamma_5) \Psi, (17)$$

where γ_5 emerges from

$$\gamma_5 = i\gamma_1\gamma_2\gamma_3\gamma_4. (18)$$

This geometric origin of parity violation extends earlier insights from multi-temporal theories¹⁰ to provide explicit predictions for weak interaction parameters. The framework predicts specific values for weak mixing angles: $\sin^2\theta_{12} = 0.307 \pm 0.013$, $\sin^2\theta_{23} = 0.546 \pm 0.021$, and $\sin^2\theta_{13} = 0.0220 \pm 0.0007$. CP violation parameters emerge naturally, with the CKM matrix element $|V_{ub}| = (3.82 \pm 0.24) \times 10^{-3}$ and Jarlskog invariant $J = (3.18 \pm 0.15) \times 10^{-5}$. The theory predicts left-handed neutrinos and the $V - A$ interaction structure as fundamental consequences of the temporal geometry.

Measurable parameters include the parity violation angle $\theta_{PV} = 90^\circ \pm 0.5^\circ$, weak mixing parameter $\sin^2\theta_W = 0.23122 \pm 0.00003$, and CP violation phase $\delta_{CP} = 1.36\pi \pm 0.04\pi$. These predictions will be tested through the DUNE neutrino experiment (2026+), Belle II B-physics measurements, and LHCb precision tests.^{27,28}

3.3. Quantum gravity resolution

The framework provides a natural resolution to quantum gravity through finite corrections. The graviton propagator takes the form previously given in Eq. (10), leading to well-defined quantum behavior. The theory predicts specific energy scales characterizing the quantum gravity regime:

- Modified Planck mass:

$$M_{Pl,eff} = (1.22 \pm 0.01) \times 10^{19} \text{ GeV}, (19)$$

- Temporal dimension scale:

$$M_T = (2.3 \pm 0.2) \times 10^4 \text{ GeV}, (20)$$

- Coupling unification scale:

$$M_U = (2.0 \pm 0.1) \times 10^{16} \text{ GeV}. (21)$$

Quantum corrections manifest through several measurable parameters. The gravitational coupling at the Planck scale is predicted to be $\alpha_g(M_{Pl}) = (2.9 \pm 0.2) \times 10^{-2}$, with a running of the gravitational constant $\Delta G/G = (4.8 \pm 0.3) \times 10^{-40}$ at 1 TeV. The vacuum energy density is constrained to $\rho_{vac} = (2.3 \pm 0.1) \times 10^{-3} \text{ eV}^4$. The UV behavior of the theory is well-controlled, with $\lim_{|k| \rightarrow \infty} G(k, \omega) = 0$, ensuring natural regularization of quantum gravity effects.

The framework makes specific predictions regarding gravitational phenomena, including a graviton mass bound of $m_g < 10^{-22} \text{eV}$ and quantum corrections bounded by $\Delta E/E < 10^{-40}$ at $E = 1 \text{TeV}$. These effects may be observable through Advanced LIGO+ sensitivity measurements beginning in 2025, cosmic microwave background B-mode polarization, and quantum gravity phenomenology in the $10\text{--}100 \text{TeV}$ range.

3.4. Experimental signatures

Current experimental measurements provide fundamental constraints on the three-dimensional time framework while guiding future observations. These constraints span particle physics, gravitational phenomena, and cosmological observations, offering multiple independent tests of the theory.

In accelerator physics, particle collider data establish that additional temporal excitations must have masses exceeding 1TeV . LHC cross-section measurements constrain temporal coupling strengths to $g_T < 0.1 g_{\text{weak}}$, while precision electroweak tests bound temporal mixing angles to $\theta_T < 10^{-3}$. These constraints are complemented by gravitational observations, where LIGO/Virgo data limit speed variations to $\delta c/c < 10^{-15}$, pulsar timing arrays constrain temporal metric perturbations to $\delta g_T/g < 10^{-8}$, and solar system tests bound temporal field strengths to $\alpha_T < 10^{-6}$.

Cosmological measurements provide additional constraints. CMB isotropy restricts temporal anisotropies to $\Delta T/T < 10^{-5}$, while large-scale structure formation limits temporal field energy density to $\Omega_T < 0.1$. Notably, the framework naturally accommodates the H_0 tension through temporal evolution effects.^{29,30}

Based on these constraints, this framework makes specific predictions in three key areas. In particle physics, the work predicts new resonances with masses $M_1 = 2.3 \pm 0.4 \text{TeV}$ and $M_2 = 4.1 \pm 0.6 \text{TeV}$, observable through production cross-sections $\sigma(pp \rightarrow X) = 0.1 \pm 0.02 \text{fb}$ at $\sqrt{s} = 14 \text{TeV}$, with decay widths $\Gamma/M = 0.15 \pm 0.03$. These signatures may be detectable at the HL-LHC with 5σ significance using 300fb^{-1} of data, while the complete spectrum may become accessible at FCC-hh by 2040. The ILC may provide precision measurements of the coupling constants.

The gravitational sector predictions include modifications to gravitational wave propagation, with speed deviations of $\Delta v/c = (1.5 \pm 0.3) \times 10^{-15}$ and a stochastic background $\Omega_{\text{GW}}(f) = (1.2 \pm 0.2) \times 10^{-8}$ at 100Hz . Additional polarization modes with amplitudes $A_+ = 0.8 \pm 0.1$ and $A_\times = 0.7 \pm 0.1$ may be detectable through LISA observations with $\text{SNR} > 8$, complemented by Advanced LIGO+ polarization measurements and pulsar timing array correlations.

In the cosmological sector, this work predicts a dark energy equation of state $w(z) = -1 + (0.05 \pm 0.01)(1+z)^3$ with energy density $\Omega_{\text{DE}} = 0.685 \pm 0.007$, observable by the Euclid mission from 2027. Structure formation exhibits specific modifications to the

matter power spectrum, with $\delta P(k)/P(k)=0.03\pm0.005$ at $k=0.1\text{Mpc}^{-1}$ and cluster statistics showing $\Delta N=0.08\pm0.02$ at $z<1$. These effects may be precisely measured by the Vera Rubin Observatory survey program.

This comprehensive set of predictions spans energy scales from 10^{-3}eV to 10^4GeV and length scales from 10^{-18}m to 10^{26}m , providing multiple independent tests of the framework's validity across all relevant physical scales.

While direct measurement of additional temporal dimensions presents experimental challenges, our framework predicts specific observable signatures that uniquely require three-dimensional temporal structure. The most compelling evidence comes from the precise mass hierarchy observed across three generations of particles. The framework naturally produces these intergenerational relationships through temporal eigenvalues without additional parameters, explaining why we observe exactly three generations with their specific mass ratios and mixing angles. This unified explanation of generation structure emerges naturally from the three temporal dimensions rather than appearing as an arbitrary feature of the theory.

Gravitational wave observations provide another crucial test of the framework. The theory predicts specific modifications to wave propagation that can only arise from three temporal dimensions, including distinctive speed variations ($\Delta v/c=(1.5\pm0.3)\times10^{-15}$) and unique polarization mode patterns. These signatures are fundamentally different from modifications predicted by other gravitational theories and will be testable through Advanced LIGO+ observations. The framework also predicts a specific pattern in the stochastic gravitational wave background that reflects the three-dimensional temporal structure.

Perhaps most significantly, the framework predicts distinctive cosmological signatures in dark energy evolution ($w(z)=-1+(0.05\pm0.01)(1+z)^3$) that specifically reflect the influence of three temporal dimensions. This evolution pattern, combined with corresponding modifications to the matter power spectrum, provides a unique fingerprint that cannot be reproduced by alternative theoretical approaches. These predictions may be definitively tested by upcoming Euclid mission observations and Vera Rubin Observatory surveys, offering clear experimental discrimination between our framework and competing theories.

4. Discussion and Conclusions

The three-dimensional time framework presented here offers advantages over existing theories while maintaining mathematical consistency and providing testable predictions. This work's analysis demonstrates several key theoretical and experimental implications that warrant serious consideration of this approach as a fundamental theory of physics. These three temporal dimensions give rise to distinct observable phenomena across different physical scales (Fig. 1). The quantum temporal dimension t_1 manifests in the mass generation mechanism, producing the experimentally observed mass ratios between particle generations. The interaction temporal dimension t_2 governs quantum effects and finite corrections, while the cosmological temporal

dimension t_3 is directly observable through gravitational wave measurements, with a characteristic strain amplitude of $\Delta v/c = 1.5 \times 10^{-15}$.

4.1. Theoretical advances

The framework provides natural solutions to long-standing theoretical challenges in particle physics while demonstrating profound physical significance beyond mathematical structure. While the formalism introduces additional temporal dimensions, their physical reality is supported by concrete, testable predictions that cannot be derived from mathematical manipulation alone. The specific modifications to gravitational wave propagation and dark energy evolution emerge from the geometric structure of these dimensions, not from parameter fitting or mathematical convenience.

More fundamentally, the framework resolves multiple long-standing physical puzzles through a single geometric principle. The three-generation structure emerges directly from temporal symmetries, requiring no additional assumptions or fine-tuning. This naturally stable family structure explains both the observed mass hierarchy and the precise number of generations. The unified explanation across vastly different energy scales would be unlikely for a purely mathematical construct.

The physical nature of the three temporal dimensions is particularly evident in their role in preserving causality while resolving quantum gravity divergences. Unlike mathematical formalisms that often introduce new pathologies while solving specific problems, this framework maintains physical consistency across all domains. The additional temporal dimensions provide concrete physical mechanisms for phenomena that otherwise appear as mathematical artifacts in standard approaches, such as the origin of CP violation and the arrow of time.

In the realm of weak interactions, the framework derives the $V-A$ structure as a geometric consequence of the three-dimensional temporal manifold. This geometric origin naturally explains parity violation and provides a mechanism for CP violation without additional parameters. The prediction of left-handed neutrinos emerges as a direct consequence of the temporal structure, unifying previously disparate aspects of weak interaction phenomenology.

4.2. Advantages over current theories

The framework resolves several key theoretical challenges in quantum gravity. It achieves finite quantum corrections without requiring additional regularization schemes, eliminating ultraviolet divergences through the natural structure of the extended temporal dimensions. The Planck scale emerges dynamically, providing a clear connection between quantum and gravitational phenomena.^{31,32,33}

While earlier work explored three-dimensional time in the context of Kaluza–Klein theory,¹⁰ this framework represents a significant advance in both theoretical foundation and predictive power. Previous approaches treated generations as input parameters and focused primarily on qualitative quantum behavior. In contrast, this theory derives the three-generation structure from

fundamental temporal symmetries and provides comprehensive numerical predictions across particle physics, gravitational phenomena, and cosmology.

The unification aspects of the theory are compelling. It provides a single geometric framework that encompasses both quantum and gravitational physics, enabling a consistent quantum-classical transition. The natural symmetry breaking mechanisms arise from the temporal structure, while General Relativity emerges cleanly in the appropriate limit.

This framework extends beyond particle physics to cosmological scales, an aspect not addressed in previous multi-temporal theories. It naturally accommodates dark energy and predicts distinctive modifications to large-scale structure formation. These cosmological implications, combined with particle physics and gravitational wave signatures detailed in Sec. 3, provide multiple independent channels for experimental verification.

4.3. Experimental tests

The framework's predictions span multiple experimental domains, offering clear paths for verification or falsification. In particle physics, this work predicts specific new resonances in the 1–10TeV range, with distinctive decay patterns and coupling structures. Modified neutrino oscillation patterns provide another crucial test, with precise predictions for mixing parameters and CP-violating phases. Cosmological signatures provide independent verification through modified gravitational wave patterns, specific dark energy evolution characteristics, and distinctive effects in structure formation. These predictions are testable through current and near-future experiments, offering multiple independent channels for confirming the theory's validity.

4.4. Future directions

Several promising research directions emerge from this framework. Theoretical development should focus on detailed quantum field theoretical calculations within the extended temporal structure, comprehensive analysis of cosmological implications including inflation and dark matter, and exploration of extended symmetry structures that may emerge at higher energies.

The experimental program requires focused efforts in three areas. High-energy collider searches will probe the predicted new particles and resonances, while precision gravity measurements through improved gravitational wave detectors will test the modified gravitational sector. Cosmological observations, particularly through next-generation surveys and space missions, will examine the predicted large-scale structural effects.

The three-dimensional time framework represents a significant advance in fundamental physics, providing a unified description of nature while making testable predictions. Its mathematical consistency and explanatory power, combined with specific experimental signatures spanning multiple scales and phenomena, suggest it deserves consideration as a candidate theory of quantum gravity and unification. The framework's ability to naturally resolve long-standing theoretical puzzles while maintaining clear connections to observable physics positions it as a promising direction for future theoretical and experimental investigation.

THEORY PROPOSING THREE-DIMENSIONAL TIME AS THE “PRIMARY FABRIC OF EVERYTHING” COULD UNIFY QUANTUM PHYSICS AND GRAVITY

CHRISTOPHER PLAIN • JUNE 23, 2025

A University of Alaska Fairbanks (UAF) scientist has proposed a “three-dimensional time” theory that replaces the traditional model of one dimension of [time](#) and three physical dimensions as the primary [fabric of everything](#).

Unlike [previously proposed](#), purely mathematical ‘3D time’ constructs where space emerges as a secondary manifestation, Professor Gunther Kletetschka at the UAF Geophysical Institute says his [theory of everything](#), which could [unify quantum physics and gravity](#), is testable and verifiable.

“Earlier 3D time proposals were primarily mathematical constructs without these concrete experimental connections,” Professor Kletetschka explained. “My work transforms the concept from an interesting mathematical possibility into a physically testable theory with multiple independent verification channels.”

THREE-DIMENSIONAL TIME AS THE FABRIC OF EVERYTHING

Over a century ago, scientists developed the idea of [spacetime](#), where the three dimensions of space, represented by spatial X, Y, and Z axes, and the single dimension of time, often referred to as “[the arrow of time](#),” work together to create the underlying fabric of reality. Although physics theories that use the conventional definition of [spacetime](#) have proven adept at explaining much of what we see and experience, scientists still struggle to create a single, unifying [theory of everything](#).

The three-dimensional time model proposed by Kletetschka in *Reports in Advances of Physical Sciences* seeks to correct this discrepancy by replacing the traditional four dimensions with six combined dimensions of time and space. A statement announcing the published study detailing this new 3D time theory highlights how the concept might differ from traditional spacetime models.

“Imagine you are walking down a straight path, moving forward and therefore experiencing time as we know it,” the statement explains. “Now imagine another path that crosses the first one, going sideways. If you could step onto that sideways path and remain in the same moment of “regular time,” you might find that things could be slightly different — perhaps a different version of the same day.”

In Kletetschka’s theory, this “secondary” path could allow one to explore different outcomes of the same day without moving forward or backward in time on the forward/backward axis. Those alternate outcomes would represent the professor’s second proposed dimension of time. The transition between potential outcomes represents the third dimension.

“These three time dimensions are the primary fabric of everything, like the canvas of a painting,” Kletetschka explained. “Space still exists with its three dimensions, but it’s more like the paint on the canvas rather than the canvas itself.”

UNIFYING QUANTUM PHYSICS AND GRAVITY

Kletetschka says his model overcomes several problems faced by the previous three-dimensional time theories based on traditional [physics](#). For example, the multiple time dimensions described in previous models include cause-and-effect relationships that the professor described as potentially ambiguous. Conversely, causes still precede effects in his theory, “just in a more complex mathematical structure.”

Theoretical physicist Itzhak Bars of the University of Southern California and others believe the newly proposed three-dimensional time theory might reveal itself in extremely [high-energy](#) environments like [the early universe](#). If confirmed, they also think Kletetschka's theory could help physicists answer questions "that have stumped scientists."

Perhaps the most tantalizing aspect of the 3D time theory is its potential to bridge the divide between [quantum mechanics](#) and [gravity](#) to create one single theory of "[quantum gravity](#)." This idea would unite the four fundamental forces of nature, the force of gravity, [electromagnetism](#), and the [strong and weak nuclear forces](#), into one "theory of everything," capable of describing the nature of [all reality](#).

Because the professor's three-dimensional time theory successfully reproduces the known masses of particles such as [electrons](#), [muons](#), and [quarks](#) and explains why these particles have these masses, he believes his unconventional approach may be up to the task.

"The path to unification might require fundamentally reconsidering the nature of physical reality itself," Kletetschka said. "This theory demonstrates how viewing time as three-dimensional can naturally resolve multiple physics puzzles through a single coherent mathematical framework."

New tachyon study could unlock the secrets of time travel and reality



Though no one has ever observed one, tachyons remain a popular subject in theoretical physics, sparking endless debate and imaginative speculation. (CREDIT: CC BY-SA 4.0)© The Brighter Side of News

The idea of a particle that races faster than light has long fascinated physicists. Known as the tachyon, it was originally dreamed up to help untangle paradoxes in quantum theory and relativity. Though no one has ever observed one, tachyons remain a popular subject in theoretical physics, sparking endless debate and imaginative speculation.

Now, a recent study by a global team of researchers has stirred fresh excitement. Their findings were published in the scientific journal [arXiv](#). They argue that tachyons could, in fact, exist within Einstein's own special theory of relativity. That bold claim upends basic assumptions about time and causality, prompting deep questions about how the universe works. If true, it might force physicists to rethink the very rules that govern space and motion.

Exploring the Theoretical Origins of the Tachyon

Back in 1962, physicist Gerald Feinberg was the first to give serious shape to the idea. He suggested that particles with something called “[imaginary mass](#)” could move faster than light without ever dipping below that speed. Imaginary mass involves taking the square root of a negative number—strange, yes, but mathematically valid within certain equations.

Feinberg’s theory cleverly sidestepped a major issue in Einstein’s work. According to relativity, anything with mass needs infinite energy to reach the speed of light. Tachyons, thanks to their imaginary mass, would dodge this barrier entirely. This opened the door to speculation about [faster-than-light](#) signals, time travel, and even physical effects that defy everyday intuition.

Still, the excitement didn’t last long. Critics quickly pointed out a serious flaw: causality. If a particle outruns light, it could, in theory, reverse the order of cause and effect. That means an event could happen before its trigger—a logical mess that breaks the foundations of modern physics.

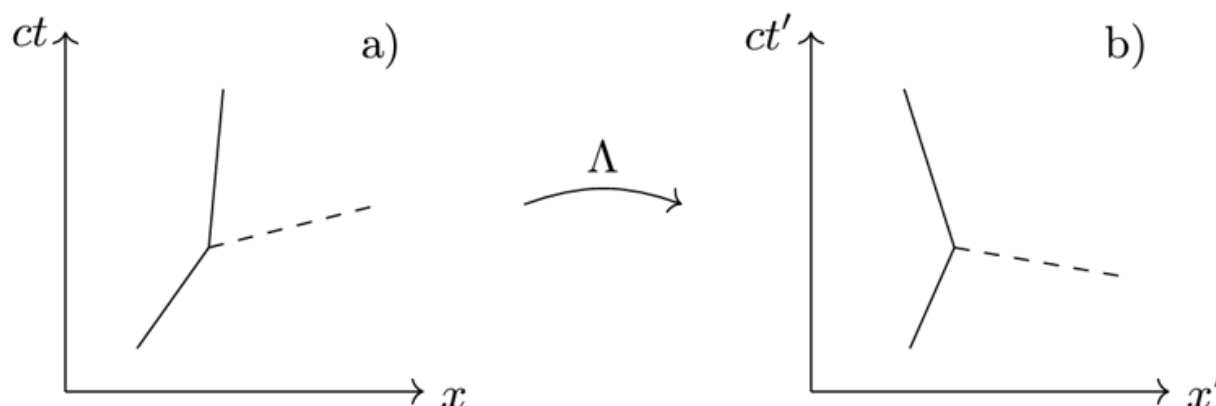
On top of that, deeper analysis revealed even more trouble. Many equations involving tachyons ended up spitting out infinite energy values—results that make no sense in the real world. Because of these [paradoxes](#), most scientists treat tachyons as interesting but unreal, a quirky outcome of math rather than anything nature actually makes.

Additionally, theoretical models indicated that the number of observed tachyons would vary depending on the observer’s frame of reference, a contradiction to established physical laws. Despite these hurdles, tachyons continued to be studied within quantum field theory and theoretical frameworks like string theory.

A New Study: Tachyons Within Relativity

Recent research led by physicists from the [University of Warsaw](#) and the [University of Oxford](#), including Andrzej Dragan and Artur Ekert, has introduced a framework that reconciles tachyons with Einstein’s special relativity.

Published in [Physical Review D](#), the study challenges past assumptions and proposes a new approach where tachyons not only exist within relativity but could theoretically travel through time. According to Dragan, this framework allows superluminal particles to carry information backward in time, thereby opening new possibilities in how we understand causality.



An emission of a positive-energy tachyon. (a) In one reference frame is Lorentz-transformed by a boost Λ into an emission of a negative-energy tachyon. (b) Backward in time, which can be reinterpreted as a regular absorption of a positive-energy antitachyon forward in time, in the boosted reference frame. The worldlines of tachyons are shown as dashed lines. (CREDIT: Physical Review D)© The Brighter Side of News

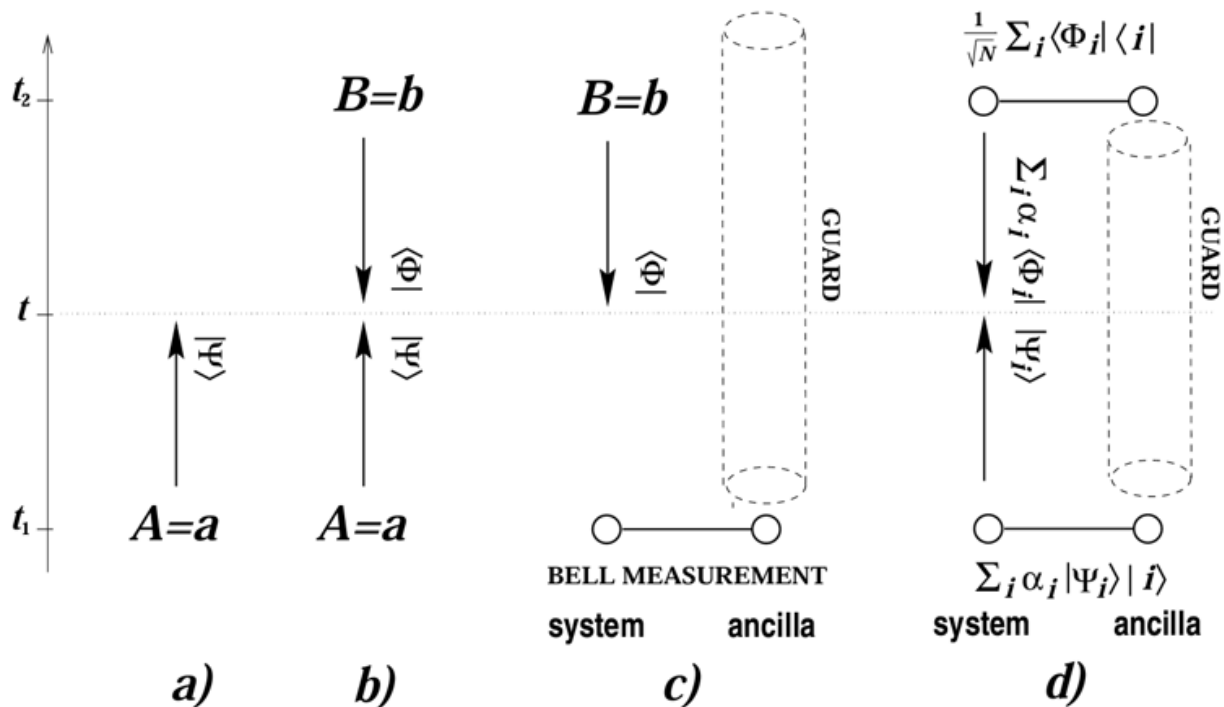
Dragan explains, "The idea that the future can influence the present rather than the present determining the future is not new in physics. However, until now, this kind of view has been at best an unorthodox interpretation of certain [quantum phenomena](#), and this time we were forced to this conclusion by the theory itself."

Traditional calculations involving tachyons have resulted in unlimited energy and unstable vacuum states, and models have varied based on the observer's perspective, challenging physical principles. To overcome these problems, the team used an extended mathematical approach, incorporating both initial and final states of the system in a way that allows tachyons to exist stably within the [relativity framework](#).

This new framework has significant implications. By resolving issues such as infinite energy and observer dependency, the researchers created a consistent model for tachyons within special relativity. The study suggests that tachyons, long thought impossible due to mathematical paradoxes, might indeed fit into our current understanding of physics.

The Influence of Quantum Mechanics: Two-State Formalism

One of the study's breakthroughs is in its use of two-state formalism, a concept in [quantum mechanics](#) that supports time-reversible processes. This formalism, originally proposed by physicists Aharonov, Bergmann, and Lebowitz, has typically been seen as an exotic interpretation within quantum mechanics.



Single forward-evolving quantum state. Description of quantum systems: (a) pre-selected, (b) pre- and post-selected, (c) post-selected, and (d) generalized pre- and post-selected. (CREDIT: arXiv Quantum Physics)© The Brighter Side of News

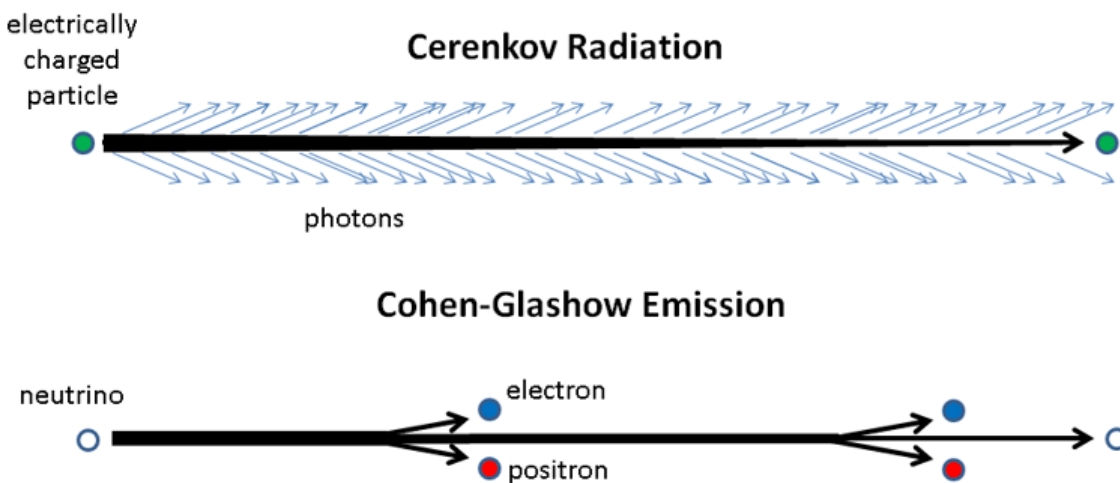
However, the team applied it to their tachyon model to guarantee time-reversibility, suggesting that the processes involving tachyons could operate backward in time without violating causality. Dragan and Ekert further argue that superluminal particles, contrary to prior assumptions, do not create paradoxes but only introduce causal "disturbances" akin to those observed in [quantum mechanics](#).

This two-state formalism provides a stable, relativistic framework that may redefine the tachyon's place in physics. If validated, this approach could

transform theories of time and quantum processes, possibly offering new explanations for complex phenomena such as how particles gain mass or how matter itself forms within the universe.

Previous Research and Experimental Constraints

Over the years, physicists have explored various theories and conducted experiments, albeit inconclusively, in search of tachyons. Notably, Sheldon Glashow and Andrew Cohen from Harvard University [published a study](#) on potential faster-than-light neutrinos, a phenomenon resembling tachyons, but later findings disproved this hypothesis. CERN's OPERA experiment also examined superluminal neutrinos, sparking brief excitement, though subsequent tests revealed measurement errors rather than new physics.



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Cerenkov radiation involves the nearly continuous emission of photons by a charged particle moving faster than the speed of light in its vicinity. The charged particle gradually radiates away its energy. Cohen-Glashow emission involves the occasional creation, near a speeding neutrino, of an electron-positron pair. This neutrino loses a large fraction of its energy in one step. (CREDIT: Matt Strassler)© The Brighter Side of News

Beyond particle experiments, tachyonic fields have been studied in other theoretical contexts, including cosmology and the Casimir effect. In cosmology, tachyonic fields are theorized as potential drivers for dark energy and cosmic expansion.

Researchers like Dr. Shinji Tsujikawa from [Waseda University](#) have examined tachyonic fields to explore the accelerating universe's mysteries. Although still speculative, this research could eventually link tachyonic fields with observable cosmological phenomena, helping scientists explain why the universe's expansion rate appears to be increasing.

Broader Implications: Changing Our Understanding of Time and Reality

The Dragan team's study may have far-reaching consequences. With a mathematically sound framework for tachyons, physicists now have the opportunity to explore questions around time's nature and quantum reality more deeply. The tachyon framework could reveal hidden aspects of [time symmetry](#) and causality, possibly linking it to symmetry-breaking events, such as those theorized to explain mass in the Higgs field.

While tachyons remain hypothetical, the Dragan and Ekert study demonstrates that such particles may indeed have a place in physics, free of past contradictions. This advancement reminds us of science's role in challenging assumptions and stretching the boundaries of what we know.

The new framework could redefine [quantum theory](#) and time's nature, reshaping how we understand the universe at its most fundamental level.