The Serious Notion That Time Could Go Backward

By Eugene F. Mallove

WE ARE ALL time travelers. We plunge toward an unknown future, fleeing from an ever-dimming past. The concept of time is so entwined in the grammar and meaning of language that it is difficult for us travelers to step back and see time for what it really is. According to the best scientific theories, our perception of time is an illusion — perhaps the grandest one in nature. Our seemingly rock-solid notions of "now," "past" and "future" crumble beneath mountains of scientific evidence that time is not what it seems.

We know that something is amiss in the way we perceive time. The summer vacation of a child seems to him an eternity, while for an adult, it feels like the short span of three paychecks.

We also know that many ancient cultures considered time to be cyclical on a grand scale of perhaps thousands of years. Once a cycle passed, the same series of historical events and human interactions would, in this view, occur all over again.

In Western culture, the Judeo-Christian concept of linear time came to replace those antique images of circling time. Recently, scientists have begun to focus on time's beginning and time's end.

Theoretical physicists are proposing seemingly incredible ideas. They are speculating that there may be an *end* to time, and that time may even, in the invisible, subatomic world of tiny particles, reverse itself.

In 1965, scientists discovered that there was low-level microwave radiation coming from every direction in space. They concluded that this was the remnant birth-cry of a universe that had started with a Big Bang. That meant that the universe of space and time had a *beginning* about 15 billion years ago, and that that 15 billion years is not terribly distant in time compared to the ages that may remain.

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DETAIL FROM "THE PERSISTENCE OF MEMORY" BY SALVADOR DALI, 1931

Why is it that time may have an end? The hottest issue in cosmology today concerns so-far invisible matter that seems to be governing the motion of galaxies. If there is enough of this invisible matter, whatever it turns out to be, its gravity may cause the universe ultimately to collapse on itself, ending time.

But time may also end if the more likely scenario of an unendingly expanding universe is the case. There may be just enough gravitating material to continue the universe's expansion indefinitely — slightly shy of the amount for collapse.

In the most remote future of that universe, stars and galaxies, planets and people — matter itself — will have decayed to an ever-more-dilute subnuclear soup. In such a universe — without tangible processes to mark time — time will have neither meaning nor direction.

Time, the mysterious grim reaper of life, will itself be dead.

All manner of time reckoning depends on the unfolding of a pattern of events. From the grains of sand falling through the hour-glass throat to the furious regular beating of cesium atoms in an atomic clock that slips barely one second in 3,000 years, we count time by the occurrence of events in space.

This leads us to some perplexing questions:

Is there such a thing as disembodied time — time without space?

If space were devoid of all objects, would there be time?

The mind recoils from this concept of a "timeless space." It instinctively imagines that metaphorical "stream of time" flowing even in that empty space. What about time's direction in an empty space? Would not past and future be hopelessly confused in such a realm? Further boggling the mind, try to imagine the absence of space itself — a favorite pastime of cosmologists apprehending the beginning of the universe. Could there be time without space? Hardly.

That time and space are inextricably connected was the revolutionary view propounded by Albert Einstein in 1905 and 1916 with his theories of relativity.

Up until then, "common sense" required that what is "now" for me is the same for everyone else — that my past and future are the same for the entire universe. For everyday commerce, these common-sense notions still suffice, yet according to relativity they are fundamentally flawed and totally inadequate under many conditions. There is no universal "now," no universal "past" and no universal "future."

See TIME, K4, Col. 3

Will We Ever Go Backward in Time?

TIME, From K1

Each frame of reference (all objects not moving with respect to one another define one frame of reference) has its own local time, and time appears to run at different rates depending on how fast one frame is moving with respect to another. Time is a very private matter. Moreover, the stronger the pull of gravity of an object, the slower time appears to run near it.

So the first illusion of time is that it is absolute, flowing steadily throughout the universe. There is no more dramatic proof that this is an illusion than the so-called "twin paradox":

We have two twins on Earth, one of whom blasts off in a super-rocket (far beyond current technology) and accelerates to 99 percent of light speed. The astronaut twin drifts for some years, then decelerates, turns around and again rockets toward Earth near light speed. She politely decelerates near Earth to soft-land near her twin sister. Upon greeting each other, the sisters realize that only five years have transpired for the astronaut (she is biologically only five years older, consistent with the rocket's clock). Yet the Earthbound sister has aged 30 years by her reckoning — biologically and clockwise.

Strange as this circumstance appears — and as far away we seem from actually enacting it with people — the physical and mathematical basis of the twin scenario has been verified many times over in laboratory experiments with accelerated nuclear particles. As these particles near light speed, they seem to decay at a much slower rate.

Moreover, the closer the super-rocket gets to the speed of light, the more dramatic the discrepancy in age between the space traveler and earthling. In principle, it would be possible for the astronaut twin to return to an Earth that has aged millions of years, while still awaiting her next promotion in the now-defunct Astronaut Corps.

With vast reserves of energy to burn and a few years of your own time, we can see that at least one-way travel to someone else's future is possible. The lesson of the twins is not so much this delightful, if not extravagant application, but that it proves beyond doubt that time is not what it appears to be.

How had this illusion escaped physics so long? According to Einstein himself, it is because in our everyday experience, "simultaneously seen" appears to be the same thing as "simultaneously happening." It is only at cosmic distances or speeds approaching that of light that this illusion begins to be noticeable. As a result, the difference between time as a feature of the universe and local time is blurred.

Take the often-quoted example of a fast-moving freight train with an observer at its geometric center. Just as the train-borne observer passes an observer standing station-

were any way to generate and receive tachyon beams. For now, tachyons are simply imaginary, and tacky science fiction.

Even though physicists have to rely on four-dimensional space-time to conveniently understand relativity, the time dimension is not equivalent to the space dimensions. For one thing, it's tough to jump up into time.

If you are intent on being a time traveler to the future, there is another way to go other than super-rocketry. You can take advantage of the slowing down of time near a source of intense gravity, for example, the black hole from a collapsed star. If a person could avoid being tidally torn apart, then he could hover for awhile in this slowed down time and come back (if he had powerful enough rockets) having aged far less than the civilization left back on his home planet. In fact, close enough to the center of a black hole, time stops completely, physicists believe.

Another feature is that we can travel in different directions in space, but we seem to be able to go in only one direction in time. It looks like there is an "arrow of time," and it points to each of our futures, never to the past. This apparent arrow of time seems to be one of time's greatest tricks, and a subject still hotly debated by physicists.

The problem is that the laws of physics, including mechanics, electromagnetism and even 20th-century quantum mechanics all work effectively and have meaning with time running backward. In essence, substitution of -T for +T in all the equations of physics describes motions and states of particles that are every bit as valid as forward-running time.

Suppose you were to watch a film of ideal, frictionless billiard balls bouncing around a table, never slowing down. It would not be possible for you to determine whether the movie was running backward or

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forward. There is simply no way to tell how to order the sequence of frames. The movie makes as much sense to the laws of physics either way. Time's arrow is lost.

Why then are we all born, live out our lives and die in one direction of time, when, at the subatomic particle level of every atom in our bodies, this whole process could run backward and still make sense to physical

This has prompted some to explain time's arrow on "cosmological" grounds, somehow tying its particular direction to the expansion of the universe, and the large-scale influence of gravity on all matter. British astronomer Fred Hoyle, wrote, "The thermodynamic arrow of time does not come at all from the physical system itself . . . it comes from the connection of the system with the outside world. . . . The arrow of time is derived from the largest-scale features of the universe."

Though most physicists would discount it, there is some evidence that an explanation for why time cannot be reversed in a way we can experience may lurk in some very peculiar and unique particle properties at the subatomic level. Since 1964, it has been known that the certain "K mesons" or kaons define the direction of time as do no other particles. Kaons participate in certain decay processes that go in only one direction, never in reverse. Is this a tiny arrow of time pointing the way for the big arrow? Probably not, but the unique behavior presents a continuing bafflement.

Back in 1945, physicist Richard Feynman came up with a clever interpretation of antimatter particles as being matter particles temporarily moving backward in time. For example, a positively charged electron (a positron) can be thought of as an electron moving backward in time and this is still consistent with the laws of quantum mechanics. Later, violations of what had been known as "charge-parity (CP) conservation" were discovered — some nuclear reactions didn't seem to add up. In order to solve this problem, Feynman's time-reversal ideas were brought out and generalized to "CPT" conservation, the combined conservation of charge, parity *and* time direction.

It is now believed that entire time-reversed domains of antimatter — the mirror images in every way of the matter we are made up of — could exist theoretically. Science writer Martin Gardner wrote in "The Ambidextrous Universe," ". . . and here we plunge into almost total fantasy — the universe may contain galaxies of antimatter in which all events, micro and macro, are moving backward with respect to our arrow of time. Two galaxies would be time reversed relative to each other in somewhat the same way they are mirror reversed. In each galaxy, intelligent creatures would be moving forward in *their* time. Each would find events going backward in the *other* galaxy." Physical law would seem to make it impossible for beings in such antigalaxies to communicate with us. Since, as we perceived it, their light would be going backward in time — converging on them — we would not even be able to see these antigalaxies.

The old problem of going into the past and preventing your grandparents from meeting highlights the paradox

Take the often-quoted example of a fast-moving freight train with an observer at its geometric center. Just as the train-borne observer passes an observer standing stationary at a rail crossing, lightning bolts strike both the front and the back of the train.

When the ground observer sees the light from each bolt at the same time, he may be sure that they happened at the same time in his frame, because the distance light travels from both the front and back of the train is the same for him). But the observer on the train's midpoint sees the forward bolt happen first, since while the light is traveling toward him, the train has moved slightly forward. Therefore, the light from the forward bolt has less far to travel and gets to the observer before the rear bolt which must travel slightly further than the front bolt.

Thus, to both observers "simultaneous" events are not necessarily simultaneous. Both observers have a correct view of what happened — each frame simply has its own local time. What makes this all the more paradoxical is that the speed of light has been constant for both of these observers, whether they were coming from or going toward the lightning bolts!

According to Einstein's relativity theory, time must be viewed as another dimension added to the three obvious dimensions of space. In this so-called "four-dimensional space-time continuum," events play themselves out.

If something starts out at a speed less than light — as do all objects we can observe — it is thought to be impossible for that thing to ever exceed light speed. There has been speculation by theoretical physicists juggling equations that the laws of physics might allow "tachyon" particles to exist. If they did, they would be particles that would always travel faster than light, requiring impossible infinite energy to slow them down below light speed. This would be the same infinite amount of energy that normal particles would require to get up to light speed. Of course, neither could cross the speed-of-light barrier in either direction.

With such hypothetical particles, one could send signals to one's past, assuming there

Why then are we all born, live out our lives and die in one direction of time, when, at the subatomic particle level of every atom in our bodies, this whole process could run backward and still make sense to physical law? The answer to this question is only partly glimpsed by modern science. Depending on which physicist or philosopher you believe, it has something to do with probabilities, the expansion of the universe and the Second Law of Thermodynamics.

The Second Law of Thermodynamics holds that in processes involving trillions upon trillions of particles, events always seem to proceed in the direction of increased disorder (entropy).

The everyday proof of this is that if you have a container with clear water on one side of a barrier and dyed water on the other side of the barrier, removing the barrier allows the dye molecules to mix throughout the entire volume, coloring all the water. You never see the dye molecules subsequently removing themselves to one corner of the container, leaving the rest clear — even though, mathematically, there is an exceedingly small chance that that could happen if you waited long enough.

The significance of the Second Law to the understanding of time is that if the universe seems to be heading in only one direction — toward less order — then it is possible to believe that time can only run in one direction.

Yet the Israeli physicist, Y. Ne'eman, writes, "Theoretical physicists are humbled by the realization that almost 150 years after the promulgation of the Second Law of Thermodynamics, they cannot yet consider the law and its supposed connection with the arrow of time as a solved problem."

Other physicists, too, are troubled by blithe acceptance of this Second Law of Thermodynamics as the "explanation" of the arrow of time. Hermann Bondi wrote, "It is somewhat offensive to our thought to suggest that if we know a system in detail then we cannot tell which way time is going, but if we take a blurred view, a statistical view of it, that is to say throw away some information, then we can. . . ."

axes.

The old problem of going into the past and preventing your grandparents from meeting highlights the paradox of backwards time travel. But general relativity points the way to some form of backward time travel in its description of certain trajectories through a rotating black hole — an object that might form after the gravitational collapse of a massive rotating star. Astrophysicist William J. Kaufmann writing in "Black Holes and Warped Space Time," noted this: "Perhaps, therefore, a rotating hole connects our universe with itself in a multitude of places! But remember, these would be different places in space and/or time. In other words, by emerging into one of these 'other universes,' you might actually be reentering our own universe in the same place but at a different time. This is a time machine!"

Black holes being the sort of unbelievable objects they are — general relativity or no — there needs to be a healthy amount of skepticism about travel to the past through a rotating black hole. Some physicists have taken advantage of one of the interpretations of quantum mechanics — the so-called "many worlds" view — to eliminate some of the paradox in travel to the past.

The many-worlds interpretation views the universe as an infinitely bifurcating structure of parallel universes, each completely out of touch with one another. With each minute motion or energy change in a single particle, the universe forks into a pair of separating universes. Time travel to the past might take an explorer *across* to another branch of this tree of universes. Conditions in that other universe might allow the traveler to fit in without disturbing causality because this other universe would be very close to being his, without actually being it.

Yet there is a sense in which time travel to the past occurs as an everyday matter. Light from distant stars and galaxies reaching us now set out on journeys from tens to billions of years ago. Although it is not a way of being where that local past was happening, simply gazing at the stars is a way of peering back at the past.