Borrowed Time

Interview with Michio Kaku

A theoretical physicist contemplates the plausibility of time-travel

by **J.R. Minkel**

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A motion picture adaptation of Michael Crichton's time-travel adventure story "Timeline" opens November 26. Crichton cites theoretical physicist Michio Kaku of the City University of New York as one inspiration for the science behind the story. Kaku -- a string theorist -- is the author of several physics books for a popular audience including Hyperspace and Visions: How Science Will Revolutionize the 21st Century and is the host of a weekly science radio show. He recently spoke with ***Scientific American.com*** *about the possibility of time-travel and his thoughts on science and popular culture. An edited transcript of that conversation follows.*

Scientific American.com: How has speculating about time-travel changed over the years?

Michio Kaku: About 10 years ago, if you were a serious physicist talking about time-travel, you'd be laughed out of the scientific establishment. People would snicker behind your back; your scientific career would be ruined; and you wouldn't get tenure. In the last decade or so, there's been a sea change with regards to the scientific attitude toward time-travel. I think Michael Crichton picked that up. And I tried to convey that in my book Hyperspace. Originally, the burden of proof was on physicists to prove that time-travel was possible. Now the burden of proof is on physicists to prove there must be a law forbidding time-travel.

SA: When did scientists first start thinking about time-travel in a rigorous way?

MK: In 1949, Einstein's colleague at Princeton was Kurt Gödel, one of the greatest logicians of the last thousand years. Gödel found a solution to Einstein's equations [of General Relativity] in which the Universe rotated. And if the Universe rotated, then in a rocket ship if you went around the Universe, you would come back before you left.

Now Einstein was very troubled by this. The river of time, Newton thought, was straight and uniform. It never deviated; it always flowed at the same rate; and it carried everything in its way. Einstein comes along and says, "Not so fast. The river of time meanders, speeds up, and slows down around stars and galaxies." The new wrinkle that Gödel showed in 1949 was that the river of time could have *whirlpools*. These are called "**closed time-like curves**". And in his memoirs, Einstein says that yes, these are solutions to his equations. But we can dismiss them on physical grounds. The Universe expands -- it doesn't rotate.

Then scientists looked back at earlier solutions to Einstein's equations and found that there were other solutions which also allow for time-travel. In 1937 [W. J.] van Stockum took an infinitely long cylinder that was spinning like a maypole and [it was later found that] if you danced around the maypole, you would come back before you left. In 1963 Roy Kerr, a mathematician, found that a spinning black hole collapses into a <u>ring</u> of compressed matter, not a dot. If you fall through the ring, you could wind up backwards in time or perhaps on another universe. The mathematicians call [such spaces] **multiply-connected spaces**. The physicists call them **wormholes**. In the late 1980s, Kip Thorne at Caltech and his colleagues found yet another class of Einstein's equations where these time machines were traversable. Like an elevator connecting parallel universes, these solutions have an 'up' button and a 'down' button. Under certain conditions, you can go through them easily just like in the movies. You can look through the looking glass and then come back.

SA: Where would the wormhole come from in that case?

MK: We would get the wormhole by grabbing it from the vacuum because they're everywhere. We think that at very small distances -- 10^{-33} centimeters -- spacetime becomes "foamy". The dominant structures at those quantum distances are probably wormholes -- little bubbles, universes that pop into existence and then pop right back out of existence. Now if you could manipulate [the so-called] quantum foam, then you could go through one of these bubbles. And in Kip Thorne's original proposal for a time machine, he said that maybe we would obtain a wormhole by grabbing one of these bubbles and expanding it, stabilizing it with ***negative energy***.

SA: Negative energy?

MK: Negative energy is energy below the vacuum state or the state of motionless nothing. Let's say we have 2 parallel plates that are uncharged. We say they are at a state of 'Zero Energy' because nothing moves. But when you actually calculate this state [using quantum field theory], you have "**virtual particles**" that dance everywhere. These virtual particles create a pressure that is greater outside the plates than it is between the plates. Therefore the plates collapse. But the plates were already in a state of Zero Energy. Therefore as they collapse, they're going to a <u>lower</u> energy state. This is called the **Casimir effect**. It is minuscule; it takes a laboratory of sophisticated equipment to pick it up. But this <u>exists</u>. This is not science-fiction. We've seen negative energy in the laboratory. And this is what I think Michael Crichton picked up on -- that there is a kernel of truth there.

SA: The idea in *"Timeline"* is that you can "fax" particles into the Past. What is the kernel of truth there?

MK: In the last 10 years, there has been enormous progress in something called **quantum teleportation**. This is not science-fiction anymore. Now -- to be real -- we're not talking about sending Captain Kirk across space and time. But we are talking about sending <u>individual photons</u> across space. In a few decades, maybe we will teleport the first virus if the virus consists of a few thousand molecules. But at the present time, that's the limit of what we can do. And we can only teleport <u>things</u> in space -- not time. But the concept of "faxing matter" is not totally out of the question. And that was also raised in my book. So there is a little bit of truth there.

SA: In *"Timeline"*, the characters travel back to France in 1357 A.D. because the wormhole happens to let out there. They have 6 hours to return. But their 6 hours in the Past are synchronized with the Present. How plausible is all that?

MK: It depends. There are many designs for time machines. Wormholes from the vacuum would connect randomly with any point in space and time, so the other end would connect God-knows-where. Probability-wise, the wormhole would be more likely to connect with the Universe <u>back</u> in time rather than the Present. And if the mouths of the wormhole are stationary relative to each other, time will pass at the same rate at each mouth.

SA: How practical would it be to build one of these time machines?

MK: In fact, the <u>energies</u> we are talking about are the energies of stars. It would take a civilization far more advanced than ours -- unbelievably advanced -- to begin to manipulate negative energy to create gateways to the Past. But if you could obtain large quantities of negative energy -- and that's a big "IF" -- then you could create a time machine that apparently obeys Einstein's equation and perhaps the laws of Quantum Theory. You need superstring theory to ultimately control all the divergences [i.e., to make sure a hail of gravitons doesn't fry you when you open or close the time machine]. Some cynics say quantum effects may still make the machine blow up. But at this point, the burden of proof has shifted. People who are skeptical of time-travel have to prove it's impossible. And so far they have failed.

SA: Wouldn't time-travel lead to paradoxes?

MK: There are about 4-or-5 main classes of paradox. The most famous is called the Grandfather Paradox. That's when you go back in time and kill your parents before you were born. If you kill your parents before you were born, how could you be born and kill your parents before you were born? There are 2 schools of thought on this. First is the Russian school. Igor Novikov [of Copenhagen University] is a well-known cosmologist. He proposes that free will is somehow abridged by going backwards in time. Something happens to prevent you from killing your parents before you are born.

Or let's say, for example, that you went backwards in time to when Queen Elizabeth's forces defeated the Spanish Armada. And let's say you give a submarine to the Spanish with machine guns. Then, of course, you're altering human history and we are all speaking Spanish now. Novikov says that's not possible because when you go backwards in time and give the submarine to the Spanish, something prevents you. Well, my attitude is that in the future, advanced civilizations might simply "**mail**" the submarine to the Spanish without any free will being abridged. Inanimate matter will go through the time machine and change the Past. That's why I tend to doubt the Novikov interpretation. It's simply too much to assume that the laws of the Universe conspire to prevent paradoxes.

SA: Then what resolves the paradox?

MK: I prefer the '**Many Worlds**' interpretation. [editor’s note: quantum physics describes a particle by a probabilistic wave function such that its position is indeterminate until the wave function "collapses" and the particle assumes a definite -- though randomly determined -- position.] The 'Many Worlds' theory simply says that maybe the wave [function] never collapses. Maybe the wave just keeps on bifurcating every time it hits an obstacle. So the timeline is constantly bifurcating because the wave is bifurcating all the time. We just happen to be in one thread of this wave. And we have the illusion that we are the only ones. In this other thread, they think they are the only Universe. The reality is that nobody's function has collapsed.

In time-travel scenarios, you would simply go from one thread to the next, one timeline to the next timeline. And the two look awfully similar. If the 'Many Worlds' theory is correct, it means that if you go backward in time and kill your parents before you were born, then they are somebody else's parents. The timeline has diverged. Your parents gave birth to you in your universe, in your timeline. So if you have the 'Many Worlds' theory, there are no paradoxes -- just different timelines.

SA: What's the value to physicists of thinking about time machines?

MK: In physics we have a theorem that if it's not forbidden, it's mandatory. So when we postulate that we understand the laws of everything, that means it must answer all "how" questions. It must answer where did the Universe come from; where did the Big Bang come from; and what is the singularity of a black hole? And here we have this huge gap in the question of causality. Attempts so far to create a "chronology protection" hypothesis to forbid time-travel have failed.

Therefore we don't really know the laws that well. When you look at the calculation, it's amazing that every time you try to prove or disprove time-travel, you've pushed Einstein's theory to the very limits where quantum effects must dominate. That’s telling us that you really need a "Theory of Everything" to resolve this question. And the only candidate is string theory. So that's why we should study these things, even if we can't build one of them for millennia.

SA: And does string theory give any insight so far into these questions?

MK: No. String theory gives you trillions of solutions. Each solution is a well-defined solution to Einstein's equations and the Quantum Theory. So there is a **Multiverse** [many possible universes, perhaps co-existing] in string theory. However, string theory is also compatible with the Copenhagen interpretation [an alternative to 'Many Worlds']. So string theory does not rule out either interpretation. Personally, I believe that whether-or-not the 'Many Worlds' theory is correct will be decided by string theory. And string theory seems to lean toward the Multiverse idea.

SA: So why do you think we haven't seen any time tourists?

MK: If you go down the road and see an anthill, do you go down to the ants and say, "I bring you trinkets. I bring you nuclear energy. I give you DNA technology"? The answer is 'no'. And for the most part, you might even step on them. The distance between the ant and us -- scientifically speaking -- is comparable to the distance between us and a civilization that can manipulate the Planck energy [required to probe very small distances and operate a time machine].

We are too arrogant and self-centered to believe that they would be interested in us enough to want to visit us and give us technology. For the most part, they may not care. However, I should point out that if one day someone knocks on your door and claims to be a great great-great-great-granddaughter who has decided to visit you in the Past, don't slam the door. Because who knows? Maybe they have access to a time machine.

SA: How do you feel about the influence of popular culture and science fiction on physics?

MK: Scientists, historically, are embarrassed by science-fiction. They want to distance themselves as much as possible. However, when you read the biographies of great scientists, you realize that a lot of them were fascinated by science fiction as children. I just finished writing a biography of Einstein called Einstein's Cosmos (due in April 2004). I had to look up the biographies of many great scientists. I was shocked to find, for example, that Edwin Hubble -- when he was a young man -- read Jules Verne. And he was fascinated by the concept of going into outer space and of going to the Moon -- stuff like that. That childhood fascination was so great that he gave up a promising law career to become an astronomer. So I think that even though scientists are embarrassed to admit this -- that as children many were influenced by Jules Verne and even Star Trek. I think there's nothing to be ashamed of. That's one reason why we should take science-fiction seriously.

But the other reason is to combat scientific ignorance in the general public. I think that anything that promotes a kernel of science -- even though it's exaggerated and hyped by Hollywood -- is a step forward. We in the "ivory tower" ultimately have to realize that in some sense we have to "sing for our supper". The cancellation of the SSC particle accelerator was a wake-up call for all high-energy physicists. Unfortunately, I think that we scientists have failed to engage the public. And I think that has negative consequences.

SA: How so?

MK: Take a look at **George Gamow**, who is now recognized as one of the great cosmologists of the last hundred years. I speculate that he probably didn't win the Nobel Prize because people could not take him seriously. He wrote children's books! His colleagues have publicly stated his writing children's books on science had an adverse effect on his scientific reputation. And people could not take him seriously when he and his colleagues proposed that there should be a **cosmic background radiation**, which we now know to be one of the greatest discoveries of 20th Century physics.

When **Carl Sagan** was engaging the public years ago, he was denied admission to the National Academy of Sciences. In the debate, it came out that many [scientists] could not take him seriously. They saw him on television. How seriously can you take someone you see on television? You see actors on television. So I think it had a negative effect on his scientific career.

SA: It sounds like things have changed, though.

MK: The sea change came when **Steven Hawking** wrote the book A Brief History of Time. He was a serious cosmologist who took the time to write a book for the general public. And it was among the best-selling books of all time. Even the publishing world had to take note of that book. I think that has made it possible for more scientists to engage the public to the point where reputable scientists can write books about Science and not have to suffer like Gamow suffered decades ago.

SA: Does this have anything to do with your radio program and why you do that?

MK: Yes. I like to engage the public because when I was in high school, I had all these questions about anti-matter, higher dimensions, and time-travel. Every time I went to the library -- every time I asked people these questions -- I would get some strange looks. Nobody could answer any of these questions. So I said to myself -- as a child -- that when I become a theoretical physicist and do research, I want to be able to answer these questions for children who ask these questions and get no answer.

SA: Do you have a favorite time-travel movie?

MK: Oh, that's a hard one. There is a problem being a physicist. And that is when you see these movies, you say, *"Well, that's not right"*. And it really ruins it. But I like the *"Back to the Future"* series. Here was a movie where you actually saw the scientist building and doing things; he was an essential character in the entire series. Doc Brown was this crazy man, but at least they showed him. He was there. He was making the series work.

SA: Even though in Hyperspace you say that the sort of time-travel found in *"Back to the Future"* wouldn't really work?

MK: Neither of the 2 theories [single or multiple timelines] is compatible with slowly fading away as you slowly change the Past. In Part Two, Doc Brown does draw a timeline forking and he does say explicitly that we went from one timeline to the next. I thought that it was interesting that in the movie, they take a position. And their position is 'Many Worlds'.

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