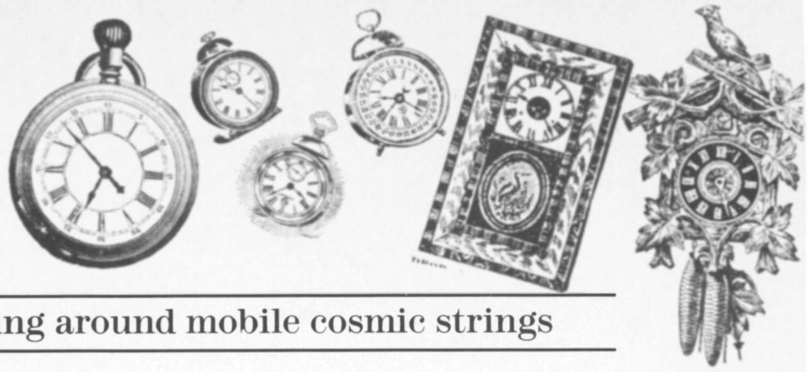
Timely Questions



Visiting the past by whipping around mobile cosmic strings

By IVARS PETERSON

A vehicle that carries its passengers into the past doesn't fit very well into a physicist's concept of the universe. Theorists generally suppose that the laws of physics – when properly formulated and interpreted – conspire to prevent backward time travel.

Indeed, the existence of time machines would lead to logical paradoxes that have no place in physics. "You could go back [in time] and kill your parents before you were born," says physicist Edward Farhi of the Massachusetts Institute of Technology. "Obviously, that can't happen."

"Physics can have things in it that are weird, but they have to be logical," he adds. "So killing your parents before you were born is crazy, whereas slowing down time is just weird."

"Most of us believe that if time machines are possible in a certain theory, then probably the theory is inconsistent with reality," contends Alan H. Guth of MIT.

Any theory that allows time travel becomes suspect, and theorists are quick to probe its intricacies to try to repair it or, more often, locate the loophole that would effectively circumvent such unphysical goings-on.

The latest time-travel conundrum, which has touched off a lively debate among theoretical physicists, arises out of a seemingly innocuous solution of the equations that embody Einstein's general theory of relativity. Discovered by J. Richard Gott III of Princeton University, this solution involves two cosmic strings – a pair of extremely thin, invisible strands of concentrated energy that warp space-time in a peculiar way.

Gott noted that two straight, parallel, infinitely long cosmic strings hurtling past each other in opposite directions could provide a suitable setting for time travel. A rocket could blast off from its home planet near the moving strings, whip around one string, loop back past the other and arrive home at the same instant it had originally departed.

"When you arrive back, you can wave at yourself taking off," Gott remarks. "That means that when you took off, you'd see yourself there waving at yourself."

This startling scenario takes advantage of the fact that some solutions of the equations of general relativity provide handy shortcuts by twisting space-time in such a way that it contains "closed time-like curves" – the technical term for looped paths that allow one to traverse relativistic space-time so that no time elapses between departure and return.

"To do this, the strings have to be moving faster than a certain speed," Gott says. But neither the strings nor the rocket ever travels faster than the speed of light, he emphasizes.

Gott's description of this theoretical puzzle in the March 4, 1991 Physical Review Letters attracted immediate attention. "What was at stake was the consistency of general relativity," says Guth. "Most of us would like to know if classical general relativity – that is, ignoring quantum effects – is capable of avoiding time machines."

Moreover, Gott's time-travel scenario looked particularly inviting. "It was so simple that it was tantalizing," Farhi says.

Amos Ori of the California Institute of Technology in Pasadena fired the first salvo. His paper, published in the Oct. 15, 1991 Physical Review D, addressed the question of whether Gott's space-time allowed time travel throughout its entire history. If it contained, in effect, built-in time machines, one could immediately label Gott's solution nonphysical.

Indeed, that's precisely what Ori found. Gott's space-time apparently contains closed time-like curves at all times. Gott had simply added to the list of valid solutions of Einstein's equations that could not possibly apply to the real universe.

However, because the definition of time in relativity has a degree of ambiguity, Ori's conclusion didn't completely settle the issue. In the Jan. 15 Physical Review D, Caltech's Curt Cutler adopted a somewhat different strategy and proved the opposite result: that closed time-like curves don't actually occupy every nook and cranny of Gott's space-time. Instead, they are confined to a certain region.

"Cutler showed that there exist some regions of this space-time that can't be visited twice," Gott says. Moreover, Cutler's novel technique introduced a way of establishing a specific time before which no closed time-like curves exist.

"That result made the debate more subtle and interesting," Farhi remarks.

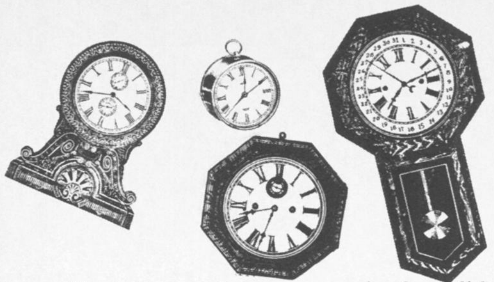
Farhi, Guth and Sean M. Carroll of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass., focused on the question of whether one could, in some sense, actually construct a Gott time machine. "Assuming that our universe didn't have a time machine to begin with, we wanted to know: Can we build one?" Farhi says.

To simplify the problem, Farhi and his colleagues considered a three-dimensional, "Flatland" space-time rather than the full-blown four-dimensional space-time of conventional relativity. In this Flatland space-time, point masses replace infinitely long, parallel cosmic strings. "You can understand everything that happens by just taking one cross section, and that cross section has one less dimension [than the original space-time]," Guth says.

Working with this simplified model, the researchers investigated what happens when a lone, stationary particle decays into two particles, which then race away from each other. Could these two particles achieve the speeds required by the Gott time machine?

The answer appeared in the Jan. 20 Physical Review Letters. Farhi and his colleagues demonstrated that an open universe, which would continue expanding forever, would never contain sufficient mass to build such a time machine. "If you had enough rest mass to accelerate the particles to meet the Gott condition, you would close the universe," Farhi says.

Relying on different theoretical arguments but using the same Flatland space-time model, Stanley Deser of Brandeis University in Waltham, Mass., and his collaborators argued in a companion paper in the Jan. 20 Physical Review Letters that a Gott time machine could not exist in the real world. Although Gott's solutions of the



Einstein equations are perfectly valid, the resulting space-time has certain characteristics that put it beyond the realm of physical possibility, they contend.

"Gott's solutions lead to closed time-like curves that are nonphysical," Deser states.

Gerard 't Hooft of the Institute for Theoretical Physics in Utrecht, the Netherlands, has since written a paper purportedly proving that a closed universe – one filled with sufficient mass to reverse its expansion – would necessarily collapse to a size smaller than any route one would need to take to circumnavigate two oppositely directed, speeding particles along a closed time-like curve.

"You start way back in time when there are no closed time-like curves, and then you show that it is impossible for the universe to evolve," Deser says. "As far as we're concerned, this result really drives the nail in. The case is closed. Classical general relativity passes another test."

Stephen W. Hawking of the University of Cambridge, England, has gone a step further by proposing a "chronology protection" conjecture to express his belief that quantum effects would prevent closed time-like curves from happening in general.

"That's certainly a possibility," Guth says.

But for some physicists, the case remains open, albeit just a crack. A number of nagging questions have yet to be resolved.

For example, Gott had noted the possibility that a finite, rapidly shrinking cosmic string in the form of a greatly stretched-out loop could also provide a setting for time travel. On some scale, such a distended loop would be difficult to distinguish from a pair of infinitely long cosmic strings.

"It's like a giant rubber band under a lot of tension," Gott says. Roughly parallel segments of a rapidly contracting loop could pick up sufficient speed to allow time travel.

However, it's not easy to solve the equations describing a cosmic rubber band. "Once you start talking about finite-size loops that pass each other, it becomes essentially impossible to solve the problem exactly," Guth notes. Moreover, a simplified Flatland space-time model provides little guidance.

Gott suggests the possibility that shrinking finite loops could easily end up as black holes. Thus, any closed time-like curves present would be invisible to an observer in the world outside the black hole's boundary.

"Several different things can happen," Gott says. For example, "you might see a loop collapsing. You fly in. You fly around the two strings just as they're passing. You visit your past, but when it comes time to get back out, you're killed when the whole thing collapses."

What actually occurs in such a case remains unclear. "Maybe you could go around and still get out in time to brag," Gott says. "We simply don't know what the solutions look like."

Ultimately, pondering the byways of time travel tests the boundaries of the laws of physics.

"We want to see whether or not closed time-like curves are prevented by general relativity," Gott says. "Maybe quantum mechanics comes in and somehow prevents them. If so, we'd like to know why. That would be very interesting."

Farhi adds, "We'd like to know: What is it about the theory that prevents this from happening, besides the fact that it's weird? How does the general theory of relativity know that it shouldn't allow a time machine?" □

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February JOURNAL OF PERSONALITY AND SOCIAL PSYCHOLOGY, 59 female college students watched a silent videotape of an anxious-looking woman talking to another woman. Half the participants were told that the woman was discussing the anxiety-provoking topics of sexual fantasies and public humiliations; the rest were told that she was describing mundane aspects of her hobbies and ideal vacations. Half the students in each of these groups mentally rehearsed an eight-digit number while viewing the videotape.

Volunteers who watched the videotape without numerical distraction rated the speaker as a generally anxious person only when they had been told she was discussing mundane topics; knowledge that she was discussing anxiety-provoking topics apparently spurred them to revise their initial characterization of the woman as anxious, the researchers say. Students kept mentally busy with the number task assigned an anxious personality to the speaker regardless of the topics they thought she was discussing; although they recalled the topics, they did not use them to revise their impressions of the woman.

Next, an experimenter told half the students to prepare to interview the woman in person and the other half to prepare to be interviewed by the woman. All participants then spent five minutes writing down their thoughts about the upcoming encounter.

At that point, formerly distracted students who expected to take a passive role as an interviewee corrected their inaccurate impressions formed while watching the woman talk about anxiety-provoking subjects. But those who expected to take an active role as an interviewer continued to ignore the influence of discussion topics and did not correct biased inferences about the woman.

In follow-up experiments employing the same videotape, distracted volunteers corrected their initial mistaken impressions when told that they would meet with the woman (a relatively familiar person) or that they should prepare to chat amiably with the woman (a familiar task). Biased impressions lingered when students were instructed to elicit disdain from the woman (an unfamiliar task) and when they were told that the woman would meet them in a room that would accommodate her wheelchair (an unusual person).

The findings sound a note of irony, Gilbert points out. "Interactions that are most important to us, with people we most want to impress, provoke a lot of self-preparation and seem most likely to lead to unwarranted inferences about those people," he maintains.

Other factors undoubtedly lead social appraisals astray, Gilbert adds. In Western cultures, the desire to predict and control the world gets translated into inferences about the inner traits of others, he suggests. And unrealistic expectations about human behavior, often fostered by a lack of appreciation for the ways in which situations shape behavior, further contribute to biased impressions. Finally, even realistic expectations about a situation (such as awareness of the power of a terrorist's threat to coerce a hostage into reading propaganda) sometimes lead to unrealistic perceptions of behavior (a sense that the hostage spoke more forcefully than was necessary).

Laboratory experiments cannot determine the day-to-day frequency of such misjudgments, but Gilbert holds that people may often navigate their social world without noticing that they have veered off course. Even psychologists who track the tricky mental currents tugging at judgments about others form their share of biased impressions, he acknowledges.

"Just because physicists study gravity doesn't mean they don't fall down," he observes with a laugh. □