Time travel and how to achieve it

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HIRO NAKAMURA in the TV show Heroes has the enviable knack of travelling through time and space. For the rest of us, it's not so easy - unless we can find a "naked" black hole. Such bodies could act not only as a "cosmic time machine", but might be responsible for the gamma-ray bursts often seen from Earth, which could be signs of time travellers coming back from the future.

This cosmic time-travel scheme using naked black holes was dreamed up in the 1970s by Fernando de Felice at the University of Padua in Italy. His idea, which he has now formalised mathematically, centres on the properties of singularities - the regions of extreme density created when stars collapse which lie at the heart of black holes. Such singularities are usually veiled by the black hole's event horizon - beyond which light cannot escape. This prevents us from observing the singularity directly, or from ever escaping if we get sucked in. However, according to Einstein's theory of general relativity, not all singularities are cloaked in this way, and it is these naked singularities that de Felice needs for his time machine.

"Naked singularities have been an embarrassment to physicists for years precisely because physical laws break down near them, opening up the possibility of time travel," says de Felice. In an effort to protect the universe from such oddities, mathematician Roger Penrose at the University of Oxford put forward his "cosmic censorship conjecture" in 1969. It stated that all singularities must come with an accompanying event horizon. "But it has been more than 30 years and this conjecture remains just that - a conjecture," says de Felice. "Nobody can justify it, or prove that you can't have naked singularities."

In fact, the case for naked singularities seems to have been growing stronger. Arlie Petters of Duke University in Durham, North Carolina, and Marcus Werner at the University of Cambridge recently suggested that a spinning black hole could shed its event horizon, leaving its core exposed, and that such a naked singularity could even lie at the heart of our own galaxy.

Around such a singularity, space-time can become so warped that a particle's path can bend back on itself in what is called a "closed time-like curve", or time loop. When that happens, a particle travelling into the future will find itself in its own past, says de Felice. His calculations show that if the collapsing star that created the singularity was large enough - about a billion times as massive as our sun - then space-time within a radius of about a billion kilometres around the singularity will be warped. This region would be large enough for humans to exploit, says de Felice. He has worked out that there are a handful of routes around a singularity that will lead passing particles - or humans - into a time loop (www.arxiv.org/abs/0710.0983).

"It takes some effort to swallow this idea," de Felice admits. The biggest problem, as with all schemes for time travel, is that it raises the possibility of the "grandfather paradox", in which a person could go back in time and kill their grandfather, thereby preventing their own birth. "I don't know why people immediately think that time travellers will be overcome with a desire to commit murder," says de Felice, "but you can see the issue." However, he adds that while this may be a philosophical barrier to accepting the concept of time travel, it has nothing to do with the laws of physics.

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Following de Felice's flight plan, budding time travellers could, in theory, hop into a spacecraft and journey to a naked singularity to travel back in time. In practice, of course, it won't be easy. For starters, you must locate a naked singularity. There is hope that some could be spotted: Petters and Werner have calculated that spinning naked singularities can act as strong gravitational lenses, magnifying the light from background stars more than an ordinary black hole would and so producing a distinctive pattern of images.

Having identified the singularity, time travellers must be prepared for a long haul. "It is unlikely that anyone among us will personally experience time travel, because we would probably die during the long space trip to the singularity," says de Felice. "If you take others with you, later generations of your descendants will be the ones that actually get to travel back in time."

While time travel may be impractical for humans, de Felice believes that photons frequently find themselves caught in time loops. Furthermore, he thinks that the mysterious gamma-ray bursts (GRBs) - giant explosions of energy that emanate from many galaxies - may be caused by these photons returning from their time-travel adventures.

De Felice calculated the fate of photons caught in time loops around singularities. "You can follow them as they travel back in time, but they can only go back so far because at some point they reach the moment when the singularity itself was formed," he says. At this point, the photons burst free of the loop and begin travelling forwards in time again. The key, says de Felice, is that to distant observers the passage of time in the loop is curiously condensed. Many photons can enter the loop at different times - separated by millions of years - but they will all appear to burst out at almost the same moment, as measured by humans on Earth. "This is why GRBs can reach such extremely high energies," says de Felice. He has calculated the profile of the afterglow of GRBs of different energies in his model. So far, the predictions fit with data, he says.

Heinrich Päs, a particle physicist at Dortmund University in Germany, who has studied time travel, is impressed. "What is really interesting here is that people are no longer just speculating that time loops can exist, but are looking at ways to prove that they exist, using observations," he says. Päs also welcomes the efforts of other groups to create mini time machines in the lab (see "Genie in the wormhole"). "If any one of these attempts to find evidence of time loops is successful it will change our understanding of, well, everything," he says.

But Päs notes that GRBs can be explained without invoking time-travelling photons. They could, for instance, be created when two neutron stars merge, or when black holes are created, he says. He wants de Felice to come up with detailed predictions to distinguish between GRBs caused by these different mechanisms.

Francisco Lobo, an astrophysicist at the University of Lisbon, Portugal, also likes the connection with GRBs. "It is certainly an interesting theoretical possibility," he says. But rather than producing a practical time machine, Lobo believes that analysing time loops will be more useful for testing general relativity. Pushing a theory to its extreme exposes its limitations, he says.

Tsvi Piran, an expert on GRBs at the Hebrew University of Jerusalem in Israel, is unconvinced: "This is extremely wild speculation." The problem, he says, is not showing that singularities can produce GRBs, but explaining why - if they exist - they don't produce other bizarre phenomena too. "The tooth fairy could pop out of a singularity just as easily as a GRB," says Piran, "or an entire concert by the Beatles."

Tooth fairies aside, NASA's GLAST probe is set to measure more GRBs when it is launched next year, and de Felice hopes that its observations will fit his predictions. "Thirty years ago, when I started out in this business, black holes were thought to be outrageous - now they are accepted," he says. "Maybe naked singularities and my cosmic time machine will have the same fate."

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Genie in the wormhole

"The Large Hadron Collider (LHC) could serve as a mini time machine factory," says Igor Volovich at the Steklov Mathematical Institute (SMI) in Moscow, Russia. If so, we might be able to detect time travel in the lab.

Particle physicists already predict that mini black holes could be produced at the LHC - the particle accelerator being built at CERN near Geneva in Switzerland - if our universe contains extra dimensions. Now Volovich and Irina Aref'eva, also at SMI, have calculated that the LHC is just as likely to create mini wormholes as it smashes particles together. These wormholes connect different regions of space-time and so can, in theory, act as portals into the past or future (www.arxiv.org/abs/0710.2696).

Only subatomic particles will be small enough to fall into these wormholes, where they will travel through extra dimensions until they pop out again, says Volovich. We cannot directly observe these extra dimensions, so as far as we are concerned the particles would effectively disappear. "When physicists add up the energies of the particles produced after a collision and find some particles missing, they will know that some might have slipped into a wormhole," says Volovich.

If we could peer into that wormhole, we would see more dramatic effects, says Theodore Tomaras of the University of Crete, Greece. He and his colleagues analysed what would happen if particles got trapped in the wormhole. Nicknamed "jinn", they would bounce back and forth in time so that, at any one moment, multiple versions would coexist (www.arxiv.org/abs/0710.3395). Tomaras thinks that jinn could be detected through their interactions with passing photons.