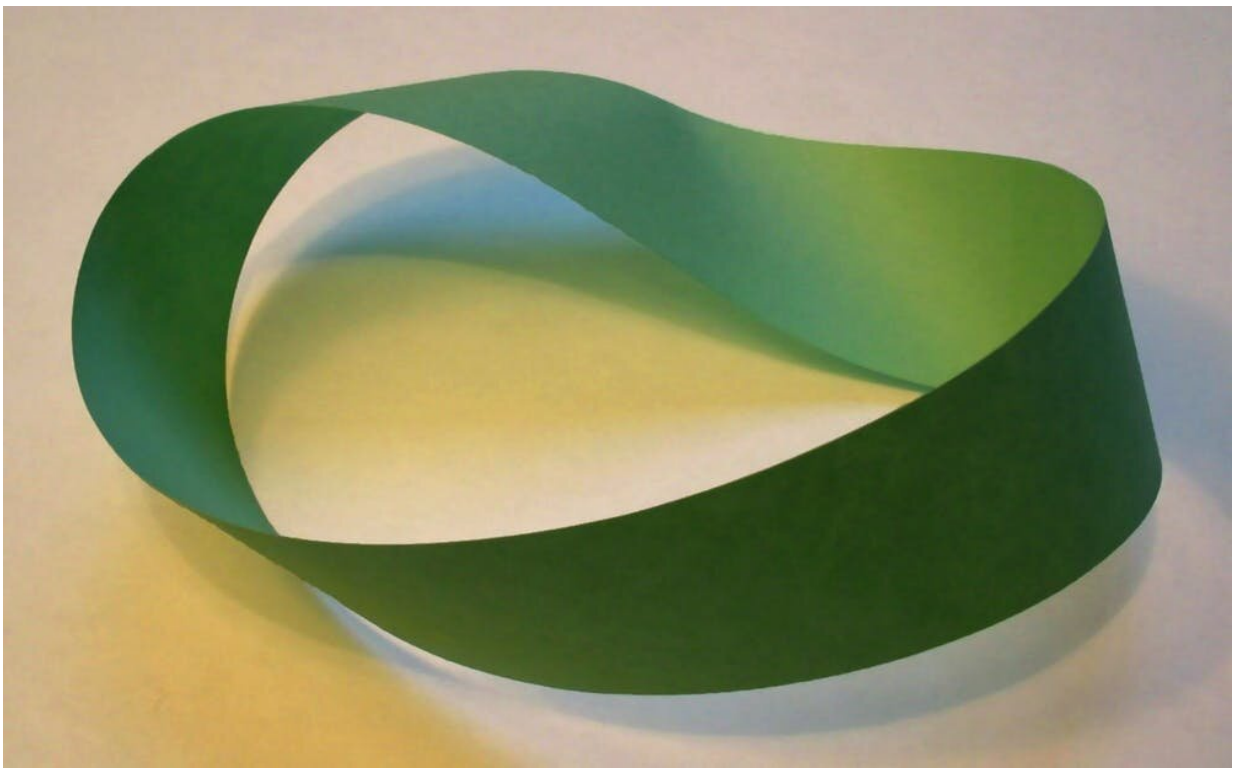
Avengers: Endgame exploits time travel and quantum mechanics as it tries to restore the universe

April 25 2019, by Michael Milford



Möbius strip. Credit: Wikimedia/David Benbennick, CC BY-SA

At the end of Avengers: Infinity War half the people (including heroes and villains) in the universe were gone in the snap of a finger from Thanos (Josh Brolin).

So how can Avengers: Endgame (in cinemas from this week) try to bring them back?

Well, with that tried and tested movie plot device: time travel. Plus a surprising amount of scientific jargon thrown in, including quantum mechanics, Deutsch propositions, eigenvalues and inverted Möbius strips .

But don't think that everything you hear during the movie was created in the minds of some crazy screenwriter. Many of the time-travel concepts in Endgame are connected, at least in name, to recent scientific theory, simulation and speculation.

Let's dive into the science of quantum time travel and discuss whether eigenvalues can really save the universe, but be warned: moderate spoilers ahead.

Time travel 101

The key premise of the movie is that the only thing that can reverse the deaths of half the universe are the things that caused those deaths in the first place: the powerful Infinity Stones.

Problem is, Thanos destroyed these in the present day, so the stones are only available in the past. Retrieving them will require a convoluted journey back in time to multiple locations by the remaining Avengers.

Is time travel actually possible? We've known since Albert Einstein posed his Theory of Special Relativity more than 100 years ago that travel *forward* in time is *relatively* easy.

All you need to do is move at close to the speed of light and you can theoretically travel millions or even billions of years into the future

within your lifetime.

But could you get back again? This feat appears to be much more difficult. Here are a few challenges and possible solutions.

The grandfather paradox

Travelling back in time can cause apparent logical inconsistencies in reality, like the well-known grandfather paradox.

If you went back in time and killed your grandfather when he was young, then you could never be born, but if you weren't born, then how did you go back and kill him?

Scientists have several theories about these time loops (physicists call them closed timelike curves). Some theories state that such loops are just physically impossible and therefore travel back in time can never happen.

But we know, also thanks to Einstein, that spinning black holes can twist up both space and time, which is why one side of the black hole is brighter than the other in the first picture ever taken of one.

Time travel in the Endgame

In the movie, the characters first make fun of many other time-travel movies such as Back to the Future and the Terminator series where changing your own past and future is possible.

Instead, Endgame goes with the alternative reality idea, where any changes back in time cause a whole new universe to be created, a so-called splitting or branching off of multiple timelines. In physics, this

idea is called the Many Worlds Theory.

To avoid this problem, the Avengers plan to borrow the stones from past timelines, use them in the present day, but return them to exactly the same moment once they have finished with them. But will it work?

Enter quantum mechanics

Quantum mechanics is mentioned a lot in the movie and there are in fact many emerging theories about quantum time travel, including some that potentially solve the grandfather paradox.

In quantum mechanics, atomic particles are more like indistinct waves of probability. So, for example, you can never know both exactly where a particle is and what direction it's moving. You only know there is a certain chance of it being in a certain place.

A British physicist named David Deutsch, who is mentioned in the movie, combined this idea with the Many Worlds theory, and showed that the grandfather paradox can disappear if you express everything *probabilistically*.

Like the particles, the person going back in time only has a certain probability of killing their grandfather, breaking the causality loop. This has been simulated successfully.

This might seem strange, and while some of the jargon used in the movie may seem a little over the top, you can be sure that real quantum science is even stranger than movie makers could ever imagine. It's clear that even scientists are struggling to make sense of the implications of quantum theory.

Terminology for effect

The time-travel theory scenes (of which there are several) are filled with technical jargon, some out of place, some in the right ballpark.

Here are a few of the terms we hear in the movie concerning time travel:

Eigenvalues: In discussing their approach to time travel, characters Tony Stark and Bruce Banner mention eigenvalues. This is most likely an example of movie maths talk for effect, as eigenvalues are a fairly low-level (basic) concept in linear algebra.

Verdict: A case of the math mumbles

Planck scale: The Planck scale is all about very small things. Planck length, time and mass are base units used in physics. A Planck length is 1.616×10^{-35}m. That's very small.

It is the distance that light travels in one unit of Planck time – which is also a very small amount of time. Given the movie is about quantum mechanics-based time travel, chatting Planck scales don't seem too far off topic.

Verdict: Planck has a point.

Inverted Möbius strip

The time-travel jargon also discusses *inverting* a Möbius strip. A normal Möbius strip is a surface with only one side. You can create one easily by taking a strip of paper, twisting it once, and then sticking it together.

Although a Möbius strip has a range of interesting mathematical

properties, its technical relevance to time travel is tenuous, beyond some high-level attempts to explain the grandfather paradox.

Verdict: Twisting theory a little.

Verdict

From a scientific perspective, it's intriguing to have a new movie with such a heavy plot foundation in time travel, and the movie doesn't pull many punches in diving straight into both the jargon and implications of various time-travel scenarios.

While some of the mathematical terminology is clearly there for effect, the plot makes a reasonable effort to adhere to current high level-thinking about time travel – to a point.

Time travel is one of those captivating scientific concepts that is perhaps furthest from implementation by scientists, and so its pivotal role in a movie about superheroes who can fly, go subatomic, destroy universes and change reality is perhaps particularly apt.

Provided by The Conversation