Travelling back in time: Neutrinos in extra dimensions

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What is time?

Why does time always proceed and never runs backwards? Or in cycles? Would the contrary be possible? Is it possible to send messages back in time?

Like: Can we send the results of the football season back to the time BEFORE the season has started to know whether we really should hire this coach?

This talk is about an idea how this COULD work by using neutrinos in extra dimensions.
This talk mixes well-confirmed science with wild scientific speculations! (which may be well motivated but are definitely not proven!)

Both may seem crazy to you!

So be alert about this distinction!

I will try to always mark the speculations with a pink MAYBE, MIGHT BE or COULD BE!
• Time and simultaneity in Einstein’s special relativity
• General Relativity and the warping of space & time
• Wormholes as time machines?
• Extra dimensions in particle physics & cosmology
• Neutrinos in extra dimensions
• 3 bold assumptions
• An extra-dimensional time machine
The velocity of light is constant

In 1887 Michelson and Morley measured the speed of light parallel and perpendicular to the Earth’s movement around the sun. Physicists realized: the speed of light is always the same, whether you are moving with it or not!

Irrespective how fast Supergirl chases the light ray, it still escapes with the same speed!

How is this possible?
Einstein 1905: Compare light-powered clocks in 2 spacecrafts:

- One spacecraft is at rest and the other one is moving.
- In the moving spacecraft light travels a longer way.
- The speed of light is always the same.
- Thus in the moving spacecraft the clock runs more slowly!
- It would stop once you reach the speed of light (impossible!).
Relativity of simultaneity

Even worse, two observers won’t agree whether two events are simultaneous! At the moment Jackie passes you in her spacecraft, two lights flash:

The red and green light reach you at the same time, so you conclude they were flashed simultaneously!

The green light reaches Jackie before the red light, so she concludes the green light was flashed first!

A moving observer can see two events happen in the reversed order!
Relativity of simultaneity

Does that mean an event can precede its cause? – No!

- Future
  - moving through space
  - moving at the speed of light
  - moving faster than the speed of light (impossible)
- Past
  - being at rest

$c \cdot t$ (lightspeed $\cdot$ time)
Relativity of simultaneity

Does that mean an event can precede its cause? – **No!**

Only in the area not accessible by subluminal signals, the sequence of events can be altered!
But if something could move faster than light?

By a superluminal signal, two events could influence each other, although not all observers would agree on the sequence!

→ An event could preceed its cause! A signal could come back before it was sent off! But superluminal signals are impossible, no?
General Relativity

Once more Einstein (1907-1915):

Gravity is not a force (in the traditional sense), but a result of the curvature of space!

The Moon circles around the Earth, not due to some attractive force but since the Earth warps the space and the Moon follows a “straight” line in this curved space!

So what does curved space imply for the problem of time travel?
...it started with a phone call in 1985:

**Carl Sagan:**
sorry to bother you, Kip...
just finishing a novel about
the human race’s first **contact**
with an extra-terrestrial civilization

want the science as accurate as possible...
...advice?

**Kip Thorne:**
Eleanor plunges into a black hole near Earth, travels through hyperspace, and emerges an hour later near the star Vega 26 lightyears away?
But it is impossible to travel from a black hole’s core to another part of our universe...
Maybe you should replace your black hole by a **wormhole**!
Wormholes for interstellar travel

Thorne came up with a curved spacetime looking like this:

- Two different points in space are connected via a wormhole!
- This allows Eleanor’s superluminal travel from Earth to Vega!
Soon Thorne realized, superluminal travel through a wormhole could transform a wormhole into a time machine:

- Jump into a wormhole
- Accelerate your spaceship to become a moving observer
- Jump back through a wormhole

You will arrive BEFORE you started your trip!
Problems of wormholes

- No one has ever spotted a wormhole.
- To warp space into a wormhole, negative energy would be required.
- Such negative energy is not known in classical physics, and seems to make space warping unstable against small perturbations.
- In quantum physics, the vacuum is not empty, but a bubbling sea of particle-antiparticle pairs.

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- Before a wormhole becomes a time machine, the energy of these pairs may become infinite!
- The infinite energy of the particle-antiparticle sea could warp space in a way that it would destroy the wormhole!
“The Time Keepers were born at the end of time, entrusted with the safety of Time by He Who Remains. The Time Keepers were meant to watch over the space time continuum just outside of Limbo, and make sure the universe thrived.” Marvel Comics

“It seems that there is a chronology protection agency which prevents the appearance of closed time-like curves and so makes the universe safe for historians.”
Extra dimensions

- To understand small objects (atoms) or large energies (like plasmas) quantum physics is necessary!

- When gravitational energy becomes very strong (Big Bang, Black Holes) a quantum theory of gravity is needed.

- It turned out that a quantum description of gravity is possible, if smallest particles are described by strings in extra space dimensions.

Why don’t we see any extra dimensions?
→ Maybe we are trapped on a 3-dimensional surface in extra-dimensional space.
Extra dimensions and gravity

Extra dimensions could explain why gravity is so weak:

*a small magnet is sufficient to lift a piece of iron and to overcome the gravitational attraction of the whole Earth*

→ Gravity could leak into extra dimensions

The Large Hadron Collider, a 27 km long particle accelerator presently built at CERN in Geneva/Switzerland (remember Dan Brown’s “Angels and Demons”), will search for the effects of extra dimensions from next year on!

→ UA-Professor Ben Harms calculates predictions for such effects!
Extra dimensions in cosmology

Temperature map of the universe measured by NASA satellite WMAP:

Very homogenous – on lengthscales which never had contact?

"our brane"

warped parallel hypersurface

Shortcuts in extra dimensions might have established causal contact and smoothed out temperature fluctuations.
Neutrinos: elementary particles (discovery Nobel prize 1995) which interact extremely weakly and being at least a million times lighter than electrons (UA Professor Andreas Piepke participates in an experiment to measure its mass)

- Why are they so light?

- The Neutrino mass may be partly in the extra dimension

→ Neutrinos tell us something about extra dimensions!
In 1995 the LSND experiment at Los Alamos has reported a measurement which indicates the existence of a new species of neutrinos, interacting even more weakly ⇒ “sterile neutrinos”

In string theory, such particles can naturally travel in the extra dimensions!

Right now, the MiniBooNE experiment under participation of UA-Professor Ion Stancu searches for these particles at the DOE operated Fermilab/Illinois!
Putting the Pieces Together

Heinrich Päs, Sandip Pakvasa, Thomas Weiler, James Dent: 3 bold assumptions

- Extra dimensions exist and are warped in a way that allows superluminal shortcuts
- Sterile neutrinos exist
- Sterile neutrinos can move in the extra dimensions

"our brane"

If all these unproven assumptions are valid, maybe it is possible to send neutrinos back in time!
Facing the wormhole problems?

- While we wouldn’t know where to search for a wormhole, the extra dimension would be everywhere.
- **Negative energy needed?** Only *in a very mild form and only in the extra dimension.*
- **Exploding quantum fluctuations?** *Less likely* in space with higher dimension.
- **Can you test it?** Just produce some **sterile neutrinos**.

So how would an extra-dimensional neutrino time machine look like?
An extra-dimensional time machine

- Create a beam of neutrinos at the north pole and point it towards the equator
- By travelling through the Earth interaction with the matter will convert the neutrinos into sterile neutrinos
- The sterile neutrinos take a shortcut through the extra dimensions, travelling effectively superluminal
- When leaving the Earth’s interior, sterile neutrinos are converted back

The neutrino beam will arrive **BEFORE** it had been sent off!

- The Earth’s rotation makes the detector lab at the equator a moving observer!
Summary

- According to Einstein, time runs more slowly once you speed up.
- Superluminal signals could even travel back in time.
- Gravity could warp space in a way that allows superluminal travel.
- One famous example: wormholes → not available, unstable.
- Another possibility: extra dimensions.
- There are experimental hints that sterile neutrinos could exist and travel in extra dimensions.
- If extra dimensions would be warped in a specific way these sterile neutrinos possibly could be sent back in time!
- So is time travel possible?
  We don’t know: probably not - but when we see what kind of physics comes in to prevent it we learn something about the Nature of time.
- ...and otherwise...

  *we would know whether the football coach is worth his money before we hire him.*