

Lecture 40: Science Fact or Science Fiction?

Time Travel

Key Ideas

Travel into the future:

- Permitted by General Relativity
- Relativistic starships or strong gravitation

Travel back to the past

- Might be possible with stable wormholes
- The Grandfather Paradox
- Hawking's Chronology Protection Conjecture

Into the future....

We are traveling into the future right now without trying very hard.

Can we get there faster?

What if you want to celebrate New Years in 3000?

Simple: slow your clock down relative to the clocks around you.

This is permitted by Special and General Relativity

Accelerated Clocks

According to General Relativity

Accelerated clocks run at a *slower* rate than a clock moving with uniform velocity

Choice of accelerated reference frames:

- Starship accelerated to relativistic (near-light) speeds
- Close proximity to a very strongly gravitating body (e.g. black holes)

A Journey to the Galactic Center

Jane is 20, Dick is 22.

Jane is in charge of Mission Control.

Dick flies to the Galactic Center, 8 kpc away:

- Accelerates at 1g half-way then
- Decelerates at 1g rest of the way
- Studies the Galactic Center for 1 year, then
- Returns to Earth by the same route

Planet of the Warthogs

As measured by Dick's accelerated clock:

Round trip (including 1 year of study) takes ~42 years

He return at age $22+42=64$ years old

Meanwhile back on Earth:

Dick's trip takes ~52,000 yrs

Jane died long, long ago

After a nuclear war, humans have been replaced by sentient warthogs as the dominant species

Advantages to taking Astro 162

Dick was smart and took Astro 162

Dick knew about accelerating clocks running slow, and so he could conclude "Ah, there's been a nuclear war and humans have been replaced by warthogs".

Unlike Charlton Heston in *Planet of the Apes*

Starship Party-poopers

The trip described is physically possible, but technologically infeasible for our culture:

1 g for 10 years accelerates the ship to close to the speed of light.

The energy requirements are enormous

Even a hypothetical matter-antimatter drive (~10% efficient) requires 1.5×10^{13} metric tons of fuel mass for each 1000 MT of payload (about an asteroid 2km across of fuel mass)

Back to the Past...

Acceleration makes a clock run more slowly, but it still runs *forward*.

To travel to the past, you have to run your clock *backwards*.

Requires faster-than-light travel

This is physically impossible according to classical Relativity

Wormholes

Tunnel of spacetime that connect two widely separated points:

- Like a black hole with no singularity

- Two singularities join across “hyperspace” and annihilate each other

- Wormhole grows in size then starts to contract

- Pinches off into 2 singularities again

Allowed by GR, but they don't last very long

A Foot in the Door ...

If any radiation or ordinary matter enters a wormhole, it hastens the pinch-off.

- Normal matter or light has “positive energy”

- If you try to fly into a wormhole, it will slam shut in your face and you will die.

Exotic Matter might have “negative energy”

- Could hold open the walls of the wormhole, allowing you to pass through.

The Cosmic Shortcut

With exotic matter, you can use wormholes for space & time travel:

- Consider a wormhole with one mouth at Earth and the other at Vega.

- The distance from Earth to Vega is 26 light years through ordinary space.

- The distance through the wormhole might be only 1 km.

Way to build a type of time machine

Journey to the Galactic Center II

Dick & Jane share a 1-meter wormhole.

- Dick carries one end on the starship.

- Jane keeps the other end on Earth.

As Dick travels, they talk via the wormhole:

It stays 1-meter long, so they agree on the time when talking through the wormhole.

Neither is accelerated relative to each other.

Dick leaves in 2006 on his 42-year journey

The Time Machine

Dick returns to Earth:

He asks Jane through the wormhole what time it is.

She says "September 2048"

Dick pops the hatch and asks a passing warthog what time it is:

The warthog says "Grunt grunt snuffle snort"

=="September57428, monkey-boy"

Dick crawls through the wormhole back to Earth where it is September 2048.

The "Grandfather Paradox"

Dick and Jane grow up, get married (to other people), and have kids.

Jane's son becomes an evil psychopathic genius who invents a way to manipulate wormholes using exotic matter in 2015.

One day in 1920, a wormhole opens in to a small Midwestern town, a heavily armed cyborg with an Austrian accent pops out and murders the small child who would have become Dick & Jane's father.

If their father never reaches maturity, and D&J are never born, how can Jane's future son create the wormhole and cyborg that kills his grandfather as a child?

This sort of thing obviously doesn't bother James Cameron or Captain Kirk one little bit.

It does, however, give Stephen Hawking the screaming willies.

Hawking's discontent, or

The "Chronology Protection Conjecture"

The laws of General Relativity permit the construction of classical time machines (e.g. wormholes using exotic matter)

The laws of Quantum Gravity, however, must *forbid* the construction of time machines (quantum fluctuations circulate through & destroy them)

“Keeps the world safe for historians”

Alternative Histories Hypothesis

A way of avoiding Chronology Protection:

In Universe 1: a cyborg pops out of a wormhole in 1920 and kills Dick & Jane’s father as a child; Dick & Jane are never born.

In Universe 2: a cyborg enters a wormhole in 2015 and vanishes. Dick & Jane’s father lives to be 85 and has 10 grandchildren.

The wormholes connect the two alternate universes.

Silliness aside

Even seemingly fanciful scenarios as exotic matter and quantum wormholes serve useful purposes in science:

Lead to deeper investigation of otherwise neglected corners of our ideas of space, time and gravity.

Can illuminate problems or limitations of our ideas (classical vs. quantum approaches)

It can even lead to surprising results.

You never know where an idea will lead....