

Temporal paradoxes

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Can atom smasher double as time machine?



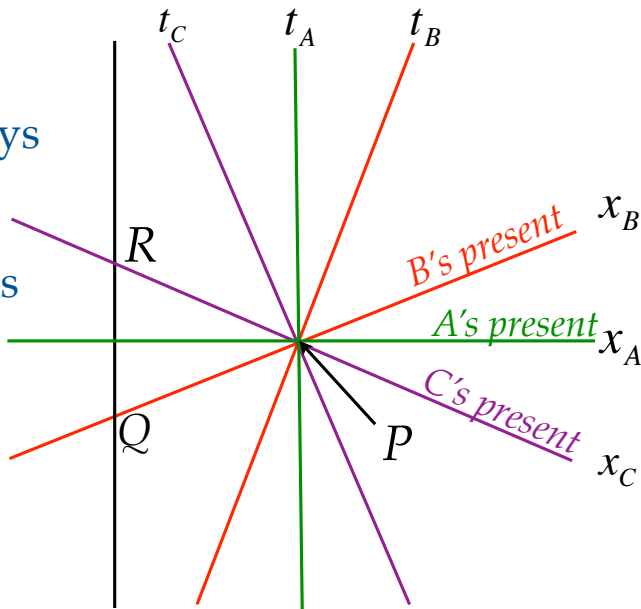
Inside the Large Hadron Collider. A view of the CMS, or Compact Muon Solenoid
(Credit: SteMaximilien Brice/CERN)

Basic equation

$$\begin{array}{c} \text{General relativity} \\ + \text{Quantum mechanics} \\ \hline \text{Time machine} \end{array}$$

A, B, & C meet at P

- A at rest
- B going right, B says P & Q are “now”
- C going left, C says P & R are “now”
- Are Q & R both “now”???



General relativity

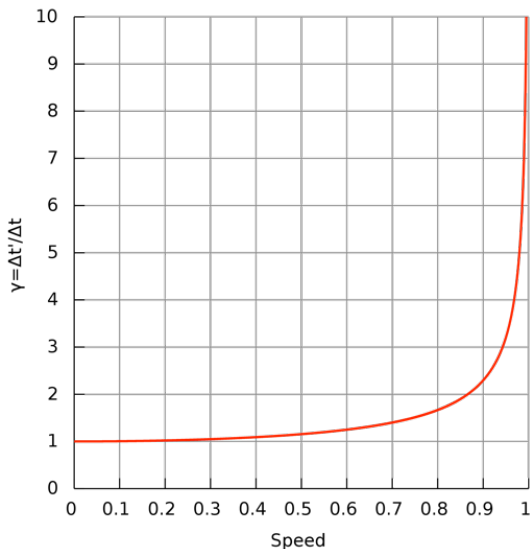
- Time is variable
- Wormholes
- Paradoxes
- Consistency principles

Time is variable

- Time dilation
- Gravitational red shift
- Frame dragging

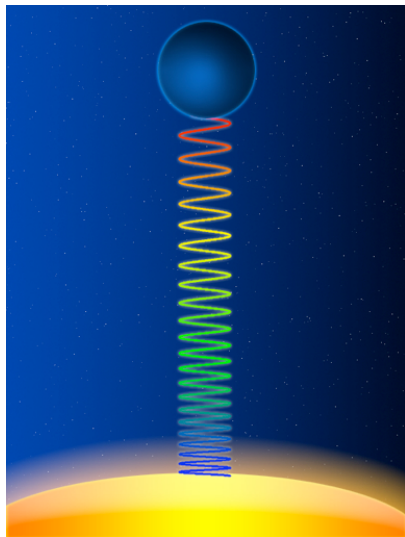
Relativistic time dilation

- At high speeds, particles seem to be using slower clocks
- We seem slower to them
- Subtracts 7 ms/day from GPS clocks

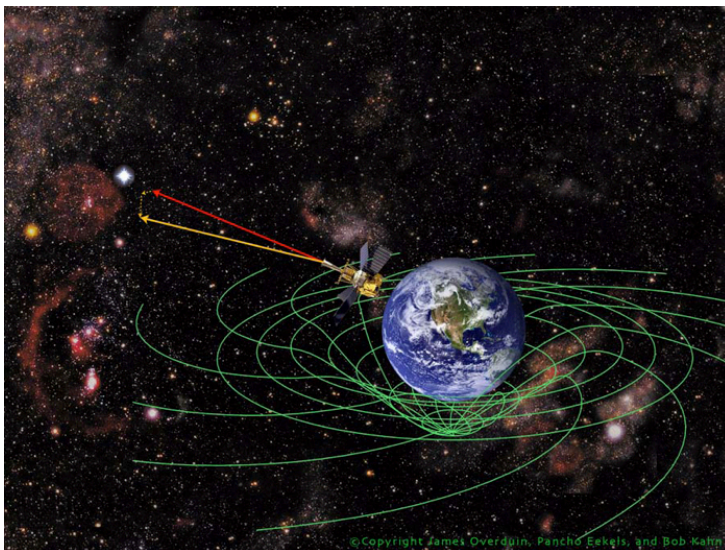


Gravitational red shift

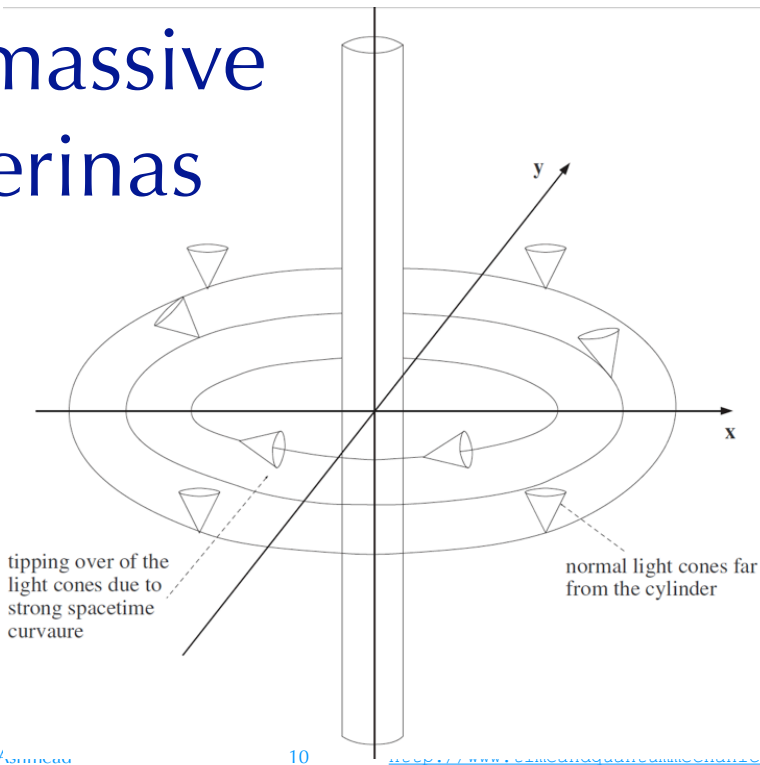
- Photon swimming up stream loses energy
- Looks as if time is slower on surface
- Adds 45ms/day to GPS clocks



Gravity Probe B



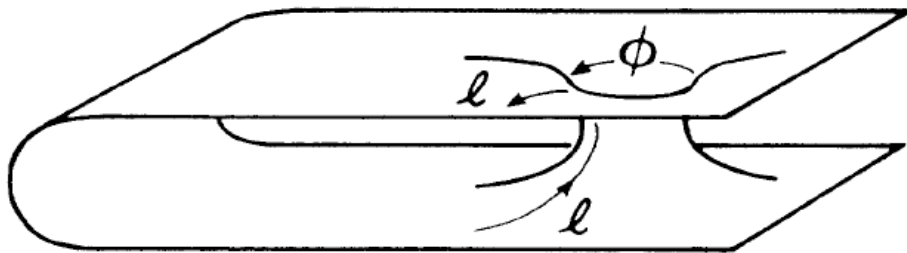
Very massive ballerinas



Wormholes

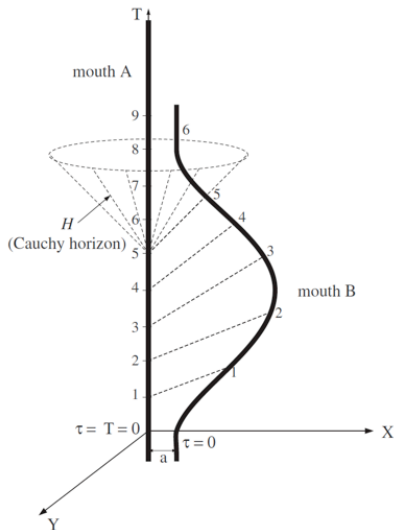
- Can be used for faster than light travel
- Built using black holes & math glue
- Can be used as time machines
- And as billiard table

Wormholes, Time Machines, and the Weak Energy Condition

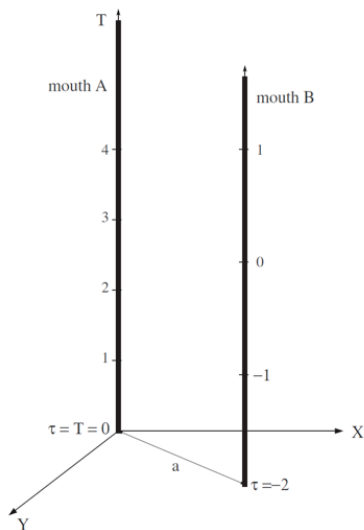


Morris, Thorne, & Yurtsever

Wormhole time machine

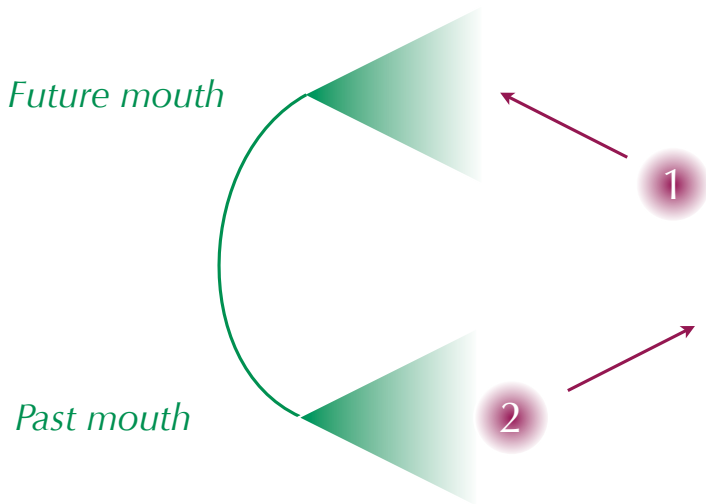


Relativistic speed



Enormous gravity

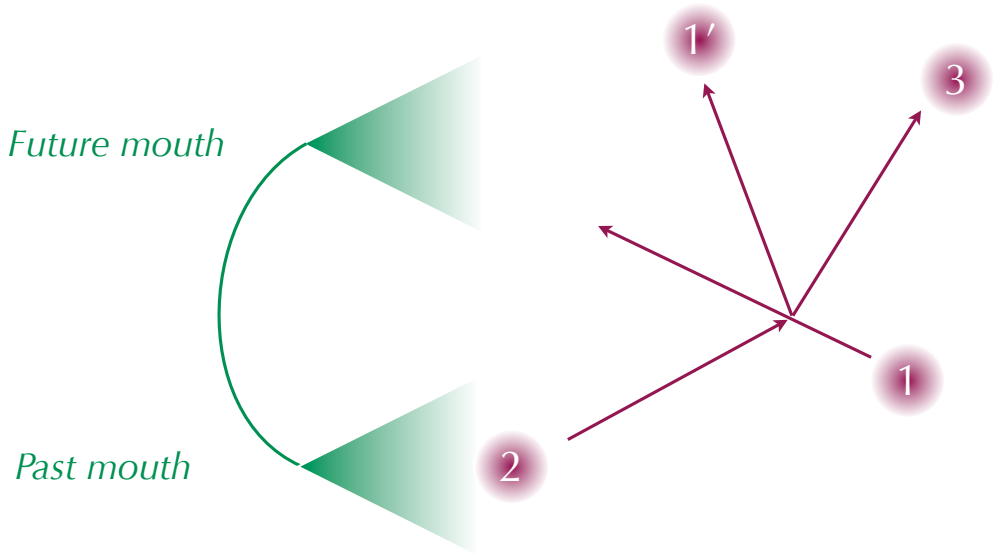
Billiards with wormholes



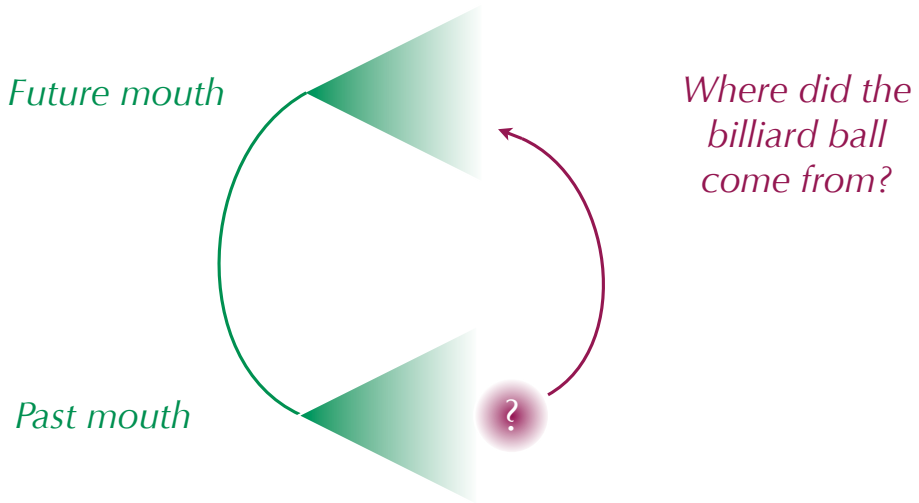
Paradoxes

- Grandfather paradoxes
- Bootstrap paradoxes
- Plausibility paradoxes

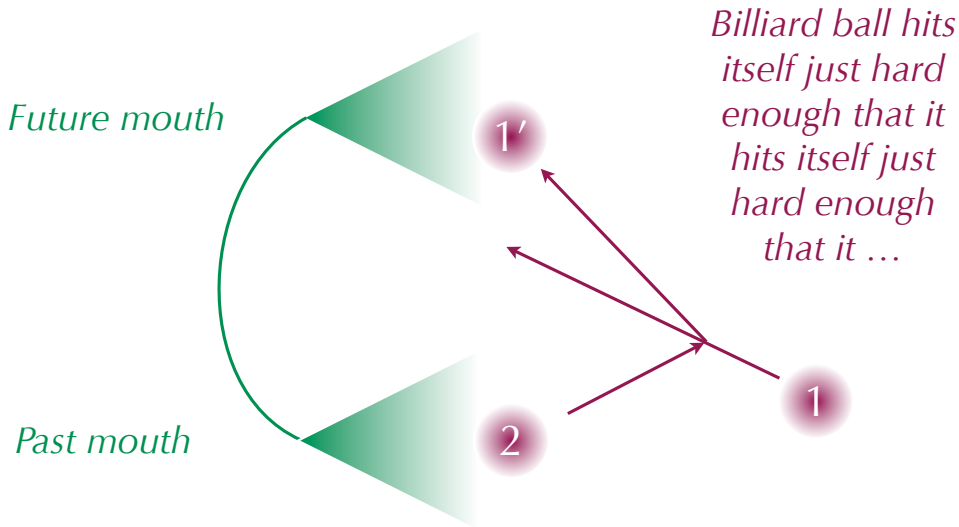
Grandfather paradoxes



Bootstrap paradoxes



Plausibility paradoxes



Chronology Protection Agency

It seems that there is a Chronology Protection Agency which prevents the appearance of closed timelike curves and so makes the universe safe for historians.

— Stephen Hawking

Weak energy condition

- If averaged energy positive, no wormholes
- But, beware of quantum fluctuations,
- black swans,
- and circular arguments.

Novikov consistency conjecture

...the only solutions to the laws of physics that can occur locally in the real Universe are those which are globally self-consistent.

— Igor Novikov

Quantum mechanics

- LHC may produce time machines
- Quantum mechanics
- Typology of time machines

Large Hadron Collider & Time Machines

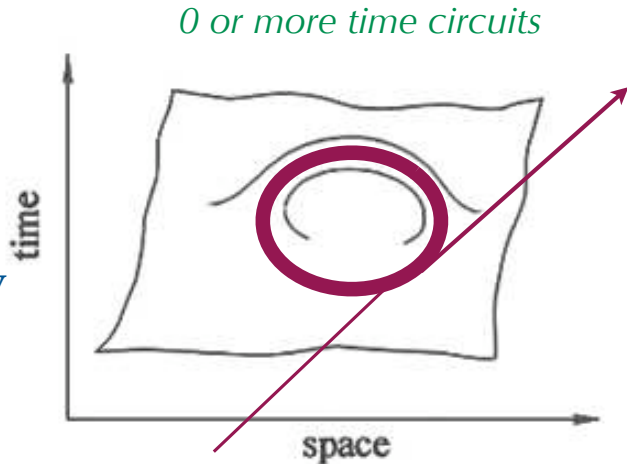
- Evanescent wormholes
- Higgs singlets

Three papers

- If LHC is a Mini-Time-Machines Factory, Can We Notice?
— Mironov, Morozov, & Tomaras
- Time Machine at the LHC
— Aref'eva, Volovich
- Causality violating Higgs Singlets at the LHC
— Ho, Weiler

Mironov, Morozov, & Tomaras

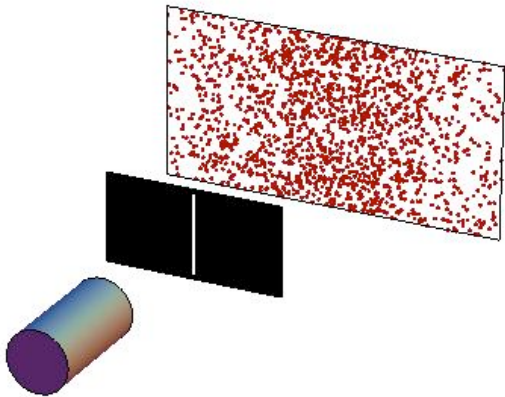
- Frequency filtration
- Unexpectedly energetic particles
- Accelerated aging
- Perceived unitarity violations
- Collective effects



Quantum mechanics

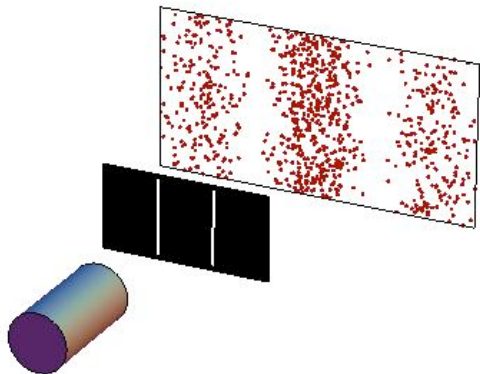
- Single slit & double slit experiments
- Sum over paths
- Measurement problem

Single slit experiment



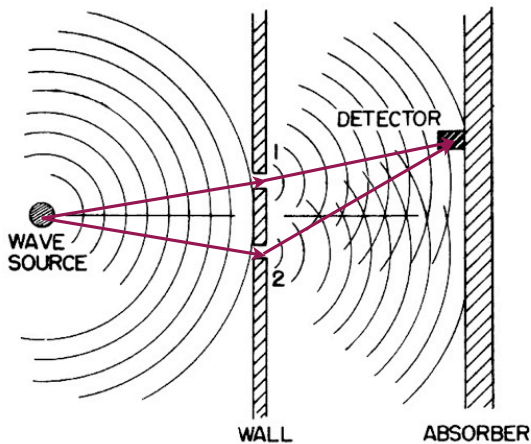
- Granular in small
- Smooth in large
- Some diffraction from edges

Double slit experiment

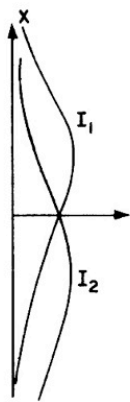


- Interference pattern is present but is emergent, not obvious
- Attempts to see “which slit” the photon went thru will destroy the interference

Sum over paths



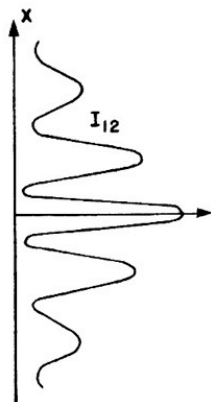
(a)



$$I_1 = |h_1|^2$$

$$I_2 = |h_2|^2$$

(b)

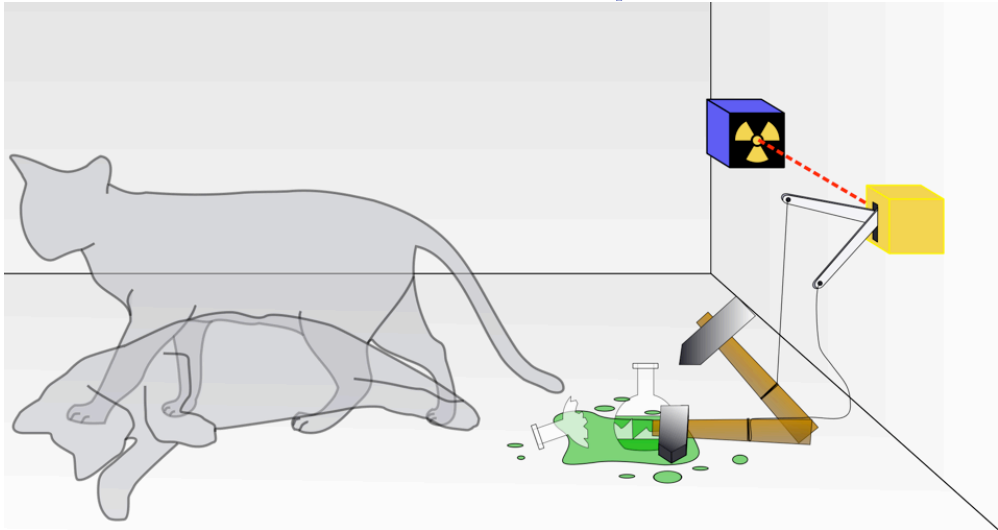


$$I_{12} = |h_1 + h_2|^2$$

(c)

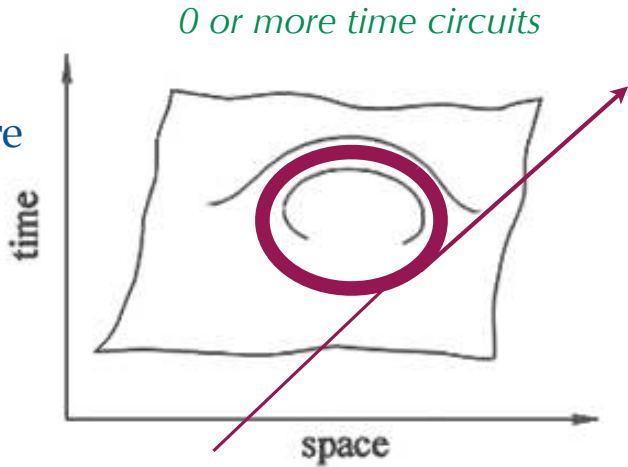
Different rules for particles & us?

Aren't we made of particles?



Typology of time machines

- Self-consistency
- Time travel or mere retrodiction
- Mechanism
- Role of observer



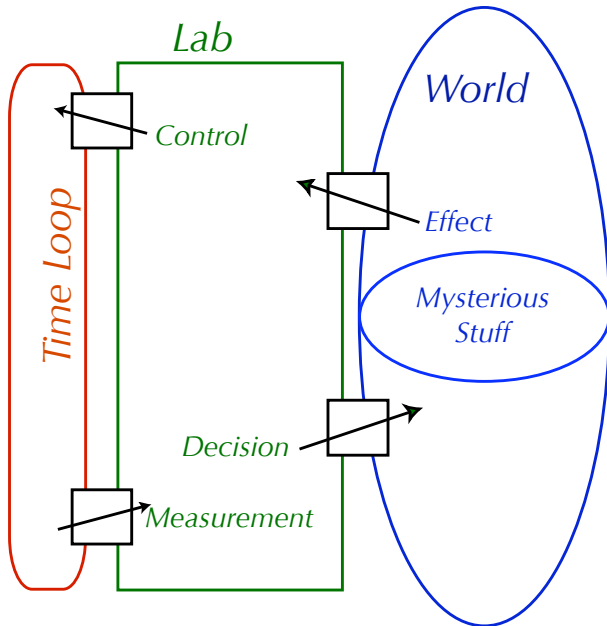
Very simple time machine

- Requirements
- Construction of the time machine
- The world matrix
- Applications

Requirements

- | | |
|-----------------------------|-----------------------|
| 1) Locally reasonable | Free will |
| 2) Globally self-consistent | No paradoxes |
| 3) Really is a time machine | Not just retrodiction |
| 4) No magic | Includes observer |

Mark I Time Machine



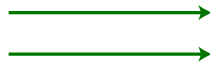
Four cases

Decision

Effect



*Success,
regardless*



*Failure,
regardless*



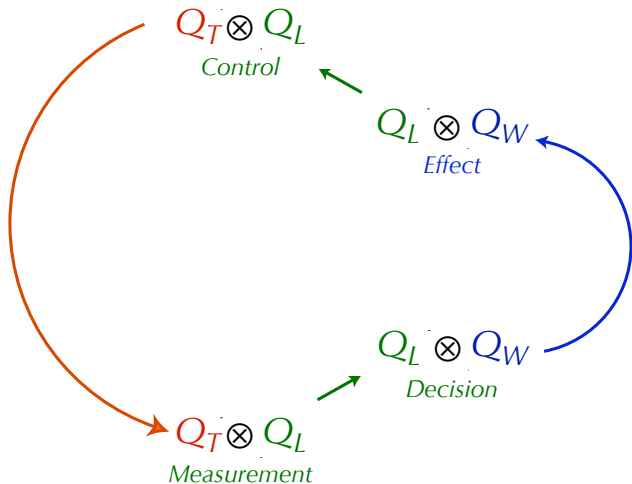
*Self-fulfilling
prophecy*



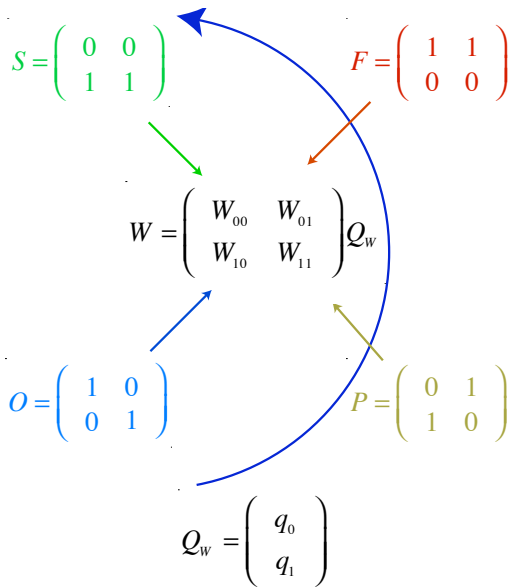
*Self-defeating
prophecy*



Time machine, lab, & world qubits



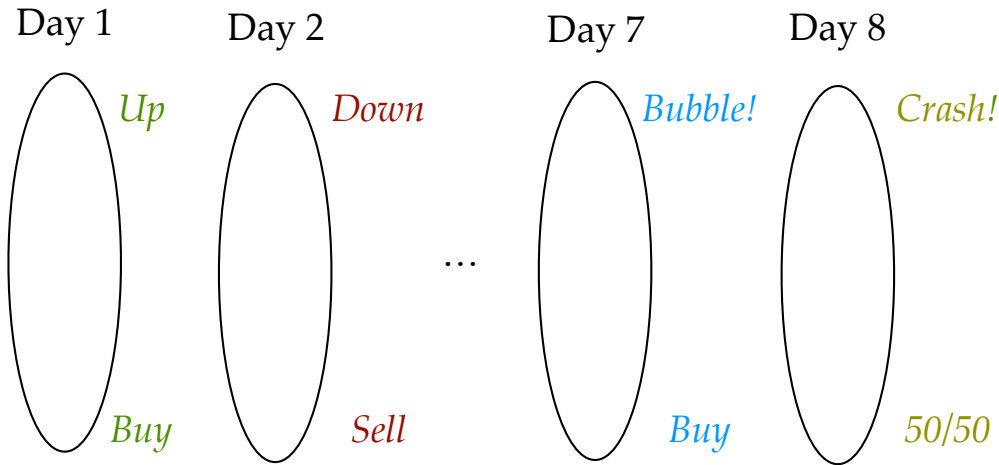
The world as matrix



Quantizing the world

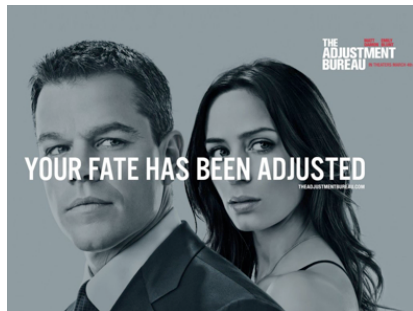
- For success & failure, there is no impact of the decision: the decision qubit is lost in the environment.
- For self-fulfilling (O), the quantum mechanical matrix is 1, which passes up and down through.
- For self-defeating (P), the quantum mechanical matrix is the spin-x matrix, which flips up & down.

A Market for Paradox

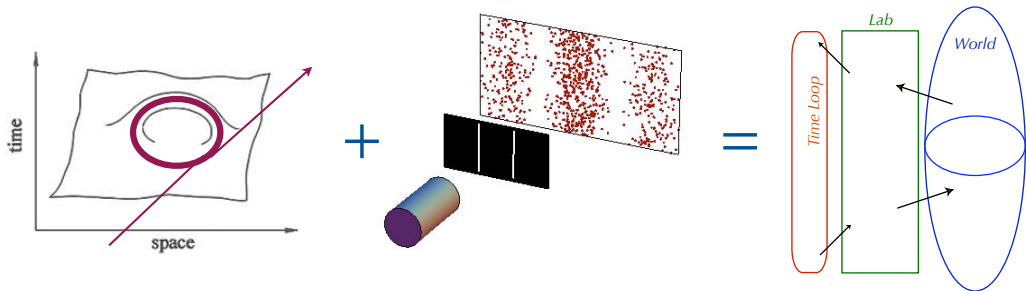


Applications

- Tests of the intersection of general relativity & quantum mechanics
- Implications for quantum computing
- Deeper understanding of philosophic issues



Radical conservatism



Thanks!

- Brent Warner
- Ferne Cohen Welch
- NASA
- Jonathan Smith, Ed & Marguerite Rutkowski, Walt Mankowski, Tom Purdom, Mark Wolverton, David Bertanni, Graham Ashmead, Shelley Handen, Bruce Bloom,...

Author	Title	Year
Thorne	Black Holes & Time Warps	1994
Visser	Lorentzian Wormholes	1994
Nahin	Time machines : time travel in physics, metaphysics, and science fiction	1997
Gott	Time Travel in Einstein's Universe	2001
Tannor	Introduction to Quantum Mechanics: a time dependent perspective	2007
Toomey	The New Time Travelers	2007
Carroll	From Eternity to Here	2010