Quantum Anomalies and the Origin of Time

Time is...

- A river flowing past at a constant rate
- Part of a spacetime continuum
- Determined by increasing entropy
- Ticking of a cosmic computer's clock
- A sociological invention ...

What is time? Are we on the brink of a new revolution?

@Shahn Majid

CamFest 2009

Proposition 1

Time is *not* a smoothly increasing quantity t independent of the observer (Newton was wrong)

Time dilation - time is experienced more slowly

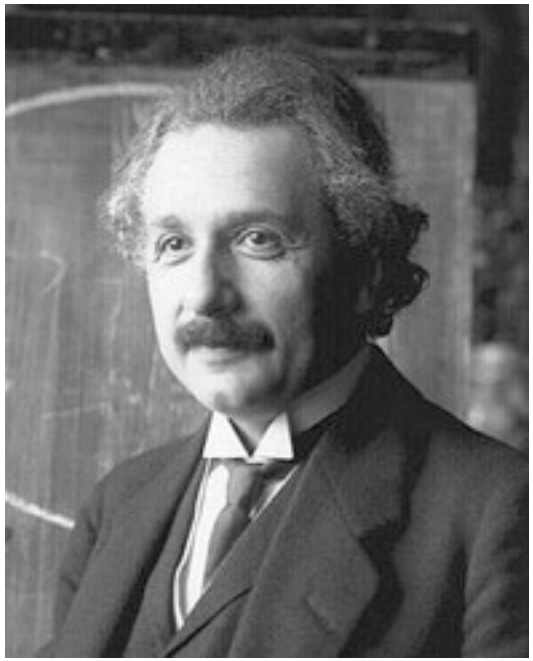
- in a strong gravitational field ...
- for someone moving at speed relative to you ...

Eg infinite time watching someone fall into a black hole, but for the person falling, it happens in a finite time.

Einstein 1905, 1917 explained all this: time is part of a 4D spacetime continuum

Proposition 2

There probably *is no* spacetime continuum (Einstein was wrong) and no-one knows what there really is

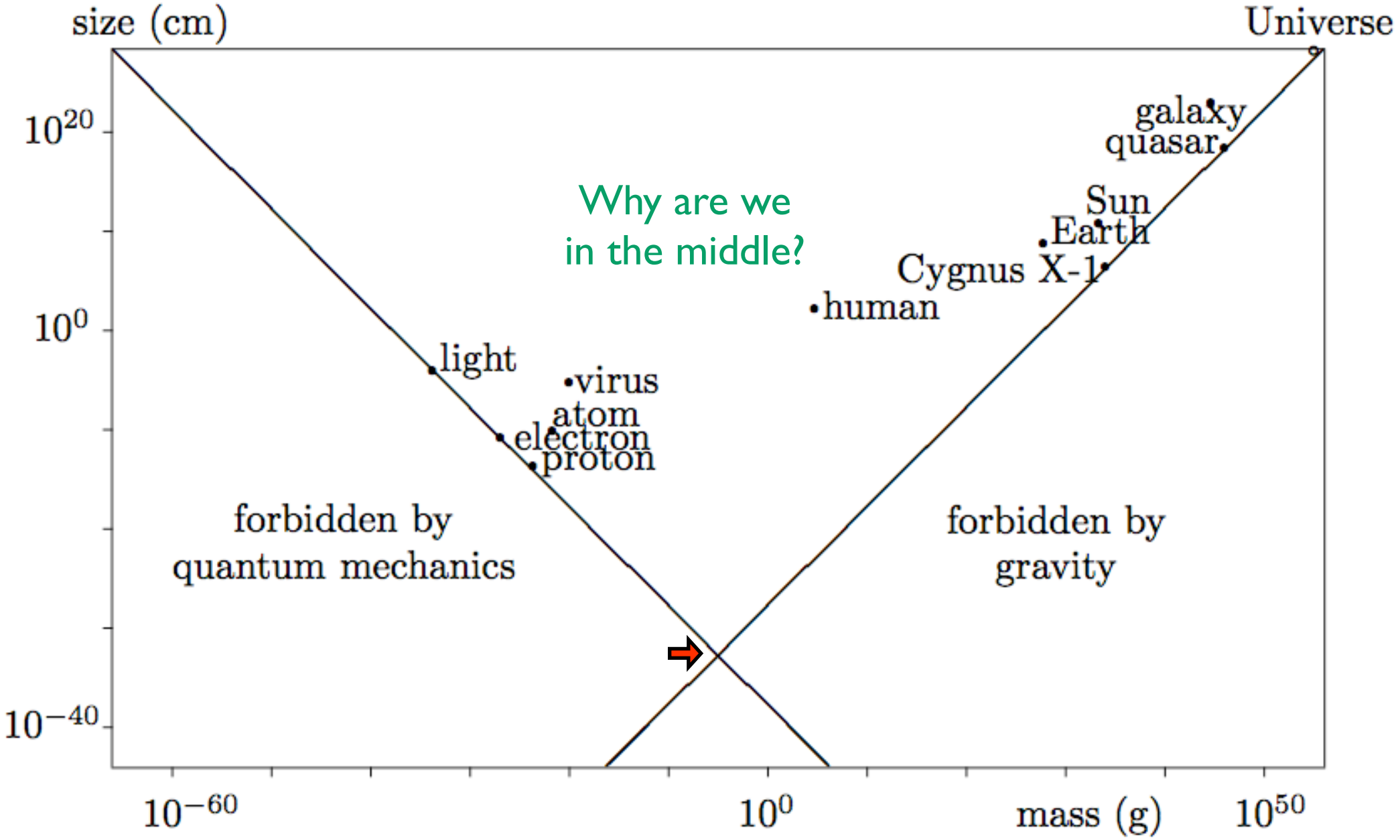


Einstein revolutionized both quantum theory and gravity but spent the later years of his life failing to unify them and never pretended otherwise

Failure to unify quantum theory and gravity even today (and string theory did not do it) has roots in a mistaken continuum assumption that space and time are infinitely divisible. Lets see why its mistaken...

The big picture

$10^{10} = 10,000,000,000$
$10^{-10} = 0.0000000001$



Planck scale = $2 \times 10^{-5}\text{g}, \quad 1.6 \times 10^{-33}\text{cm}$

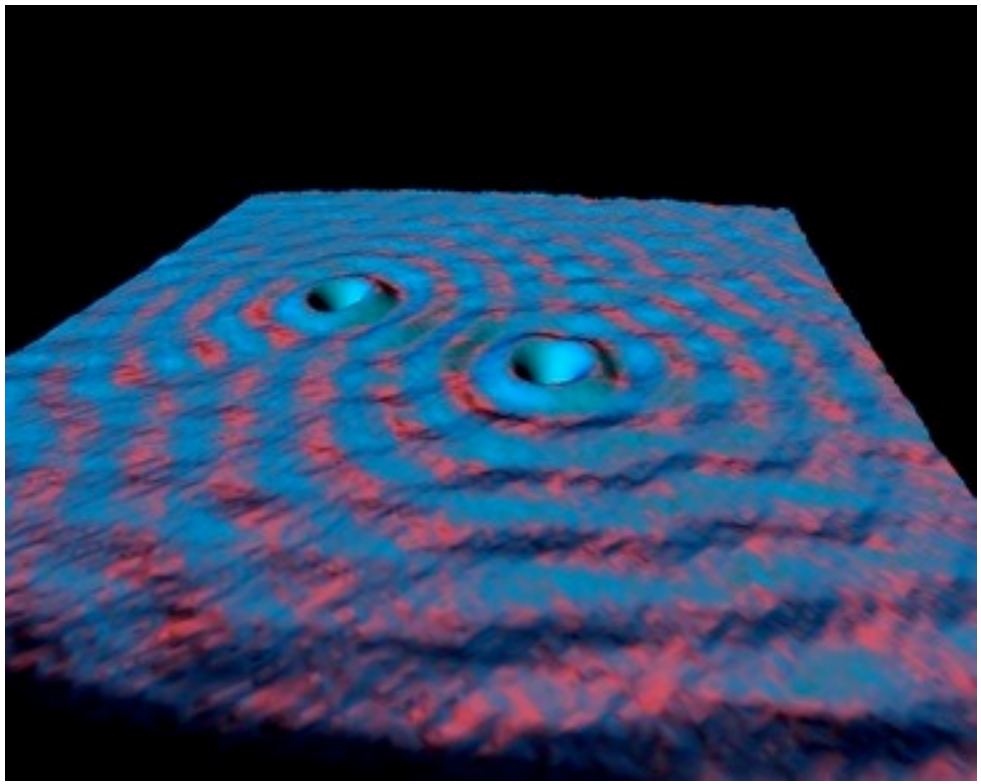
Quantum theory

Light of wavelength λ has energy $E = \hbar \frac{c}{\lambda}$

(discovered by Planck, $\hbar = 6.6 \times 10^{-34} \mathrm{Js}$)

Energy and mass are interchangeable by $E = mc^2$

(discovered by Einstein, $c = 3 \times 10^{10} \mathrm{cm/s}$ speed of light)



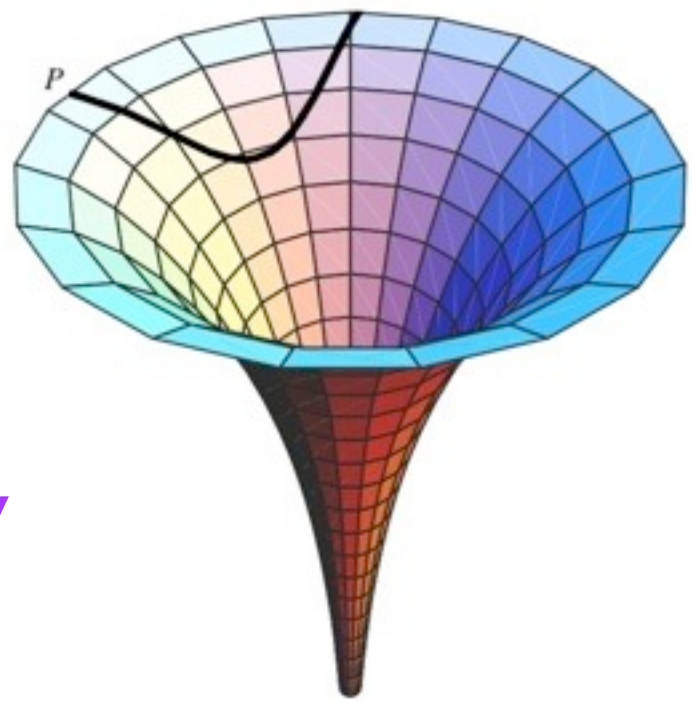
$$\lambda = \frac{\hbar}{mc}$$

This formula works for all kinds of particle - waves

The image on the left is an electron wave scattering off atomic defects in a copper crystal

Gravity (curved spacetime)

Surface of constant negative curvature. Ants moving from *P* on what at each point is for them a straight line would be deflected *outwards*



Discovered by Einstein: Curvature of 4-dimensional spacetime *is* gravity

⇨ Black hole of mass M has size

$$r = \frac{GM}{c^2}$$

($G = 10^{-8}\mathrm{cm}^3/\mathrm{gs}^2$ Newton's constant)

Artists impression of a black hole. Our own galaxy has giant black hole in its centre

To resolve smaller scales need smaller wavelengths...

Radio Telescope

Ships Telescope

Hooke's microscope

electron microscope

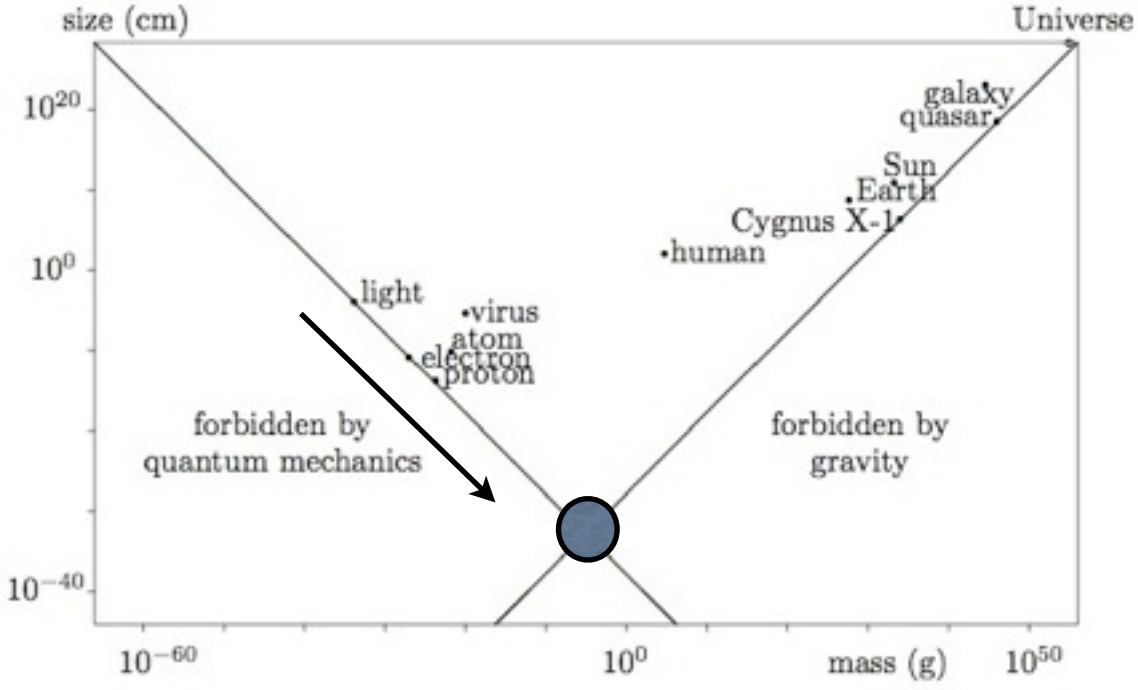
LHC "proton microscope"

decreasing wavelength, heavier quantum particles

To probe smaller and smaller distances by quantum wave-particles we need heavier and heavier particles as we move down the left slope of the graph

But ...

... as we approach the Planck scale 10^{-33}cm their mass-energy destroys the geometry we wanted to observe as they form black holes



(We also don't know if black holes evaporate, going down right slope)

➡ Conceptual inconsisteny - we assume a continuum but distances less than 10^{-33}cm are INTRINSICALLY UNKNOWABLE

➡ It is an article of FAITH to believe in smaller distances and causes insurmountable infinities

Dark energy

Dark matter and dark energy are *totally unexplained* features of our universe

70% energy in Universe mysterious uniform density $10^{-29}\mathrm{g/cm}^3$

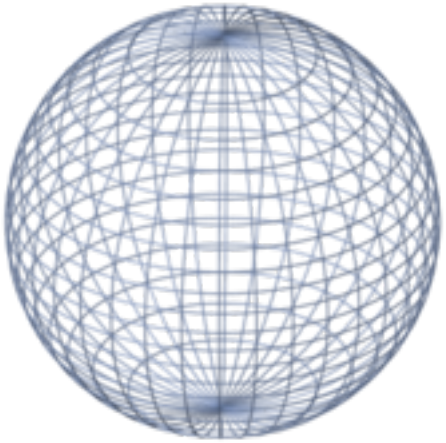
Theoretical vacuum `zero point energy' is:

- ∞ if you assume a continuum
- $10^{94}\mathrm{g/cm}^3$ if you naively cut off at the Planck length

⇨ Need a reason why its *zero* plus *small* corrections

"zero point module" in *Stargate*

Geometry



numbers x, y, z

$x^2 + y^2 + z^2 = 1$

Algebra

symbols x, y, z

rules like:

$$x(y+z) = xy + xz$$

$$xy = yx$$

$$x(yz) = (xy)z$$

etc., *and*:

$$x^2 + y^2 + z^2 = 1$$

Muhammad al-Khwarizmi
c. 708- c. 850

geometric structures
eg curved spacetime

algebraic operations

$$\mathrm{d}(xy) = (\mathrm{d}x)y + x\mathrm{d}y$$

?quantum geometry?

other algebras where $xy \neq yx$

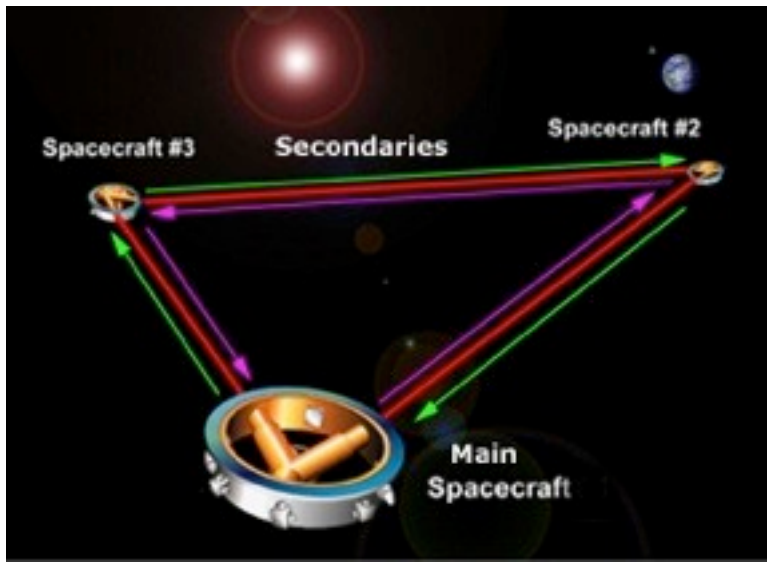
Quantum spacetime

$$xt - tx = \imath\lambda x \qquad yt - ty = \imath\lambda y \qquad zt - tz = \imath\lambda z$$

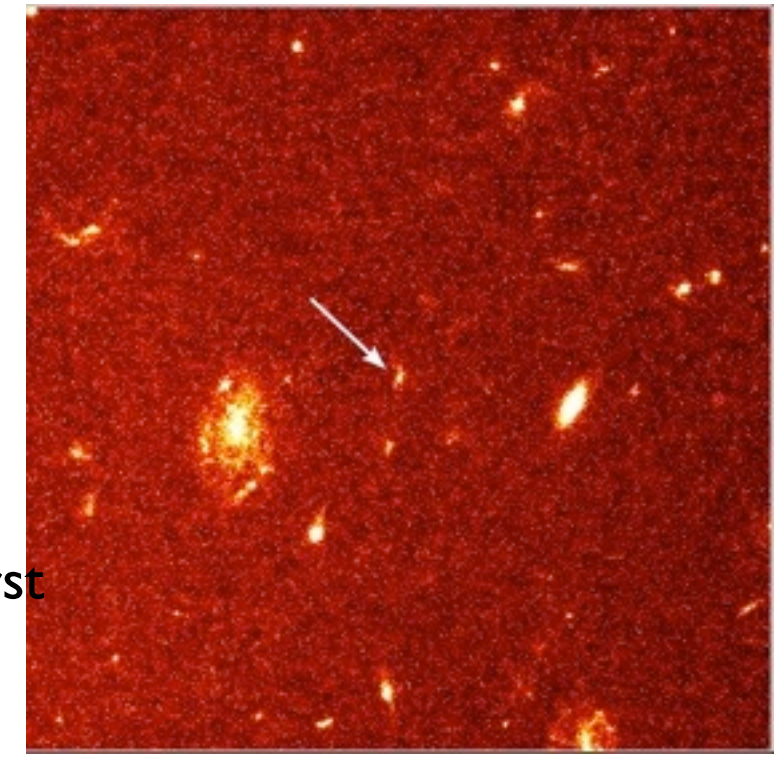
$$\lambda = 5 \times 10^{-44} s$$

- measuring *where & when* $\neq$ measuring *when & where*
- blue light travels a *little* more slowly than red light

LISA gravitational interferometer *could* be retooled to test this!



FERMI-GLAST launched May 2008 *is* testing this!



Host galaxy of gamma ray burst 12 billion light years away.

Quantum anomalies and time

~~"Unstable spacetime vortex that starships fly through..."~~

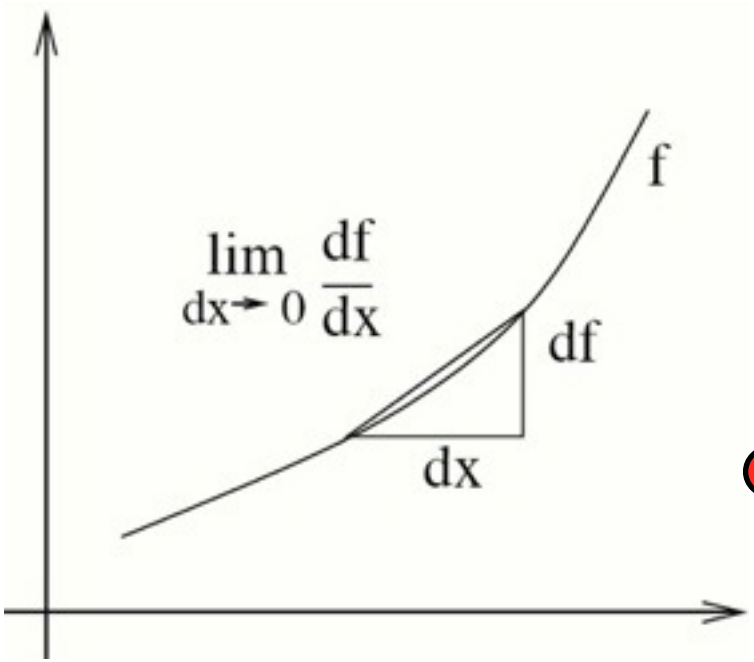
It's when a quantum system does not behave analogously to a classical one

- String theory did not work in 4 spacetime dimensions, due to a quantum anomaly ⇨ fixed by unseen higher dimensions

- In quantum spaces differential calculus typically has an anomaly ⇨ extra dimension `time' induced by the geometry of quantum space itself

Quantum high school calculus

Newton assumed dx was a number. But now ...



$$(\mathrm{d}x)y \neq y(\mathrm{d}x)$$

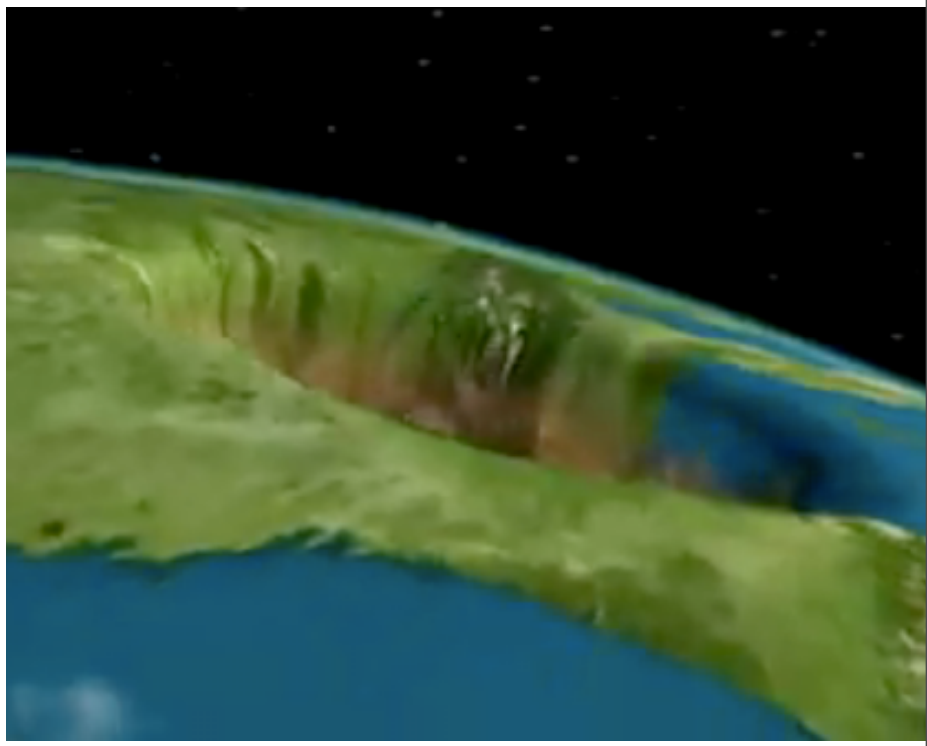
- Quantum geometries generally have a differential D with

$$Df - fD = \lambda \mathrm{d}f$$

- Equation invisible in continuum geometry
- D=dt defines an evolution of the quantum geometry
- As $\lambda \to 0$ we discover, eg, Schroedinger's equation

Imaginary dimensions and LHC

Black holes can't be formed in the LHC but if they were we don't honestly know what happens to them after they shrink to Planck size



Alain Connes - *zoo* of particles in LHC explained as extra *imaginary* spacetime dimensions (two copies) of this algebra

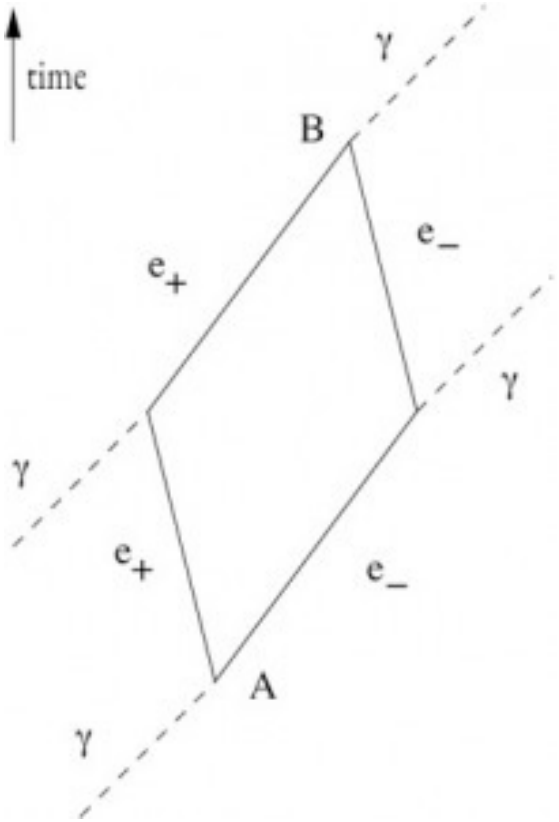
$$i^2 = j^2 = k^2 = ijk = -1$$

Graffitti carved on a bridge in Dublin in 1843 by this man

Proposition 3

Time's arrow is a sociological construct same as which side of the road to drive on

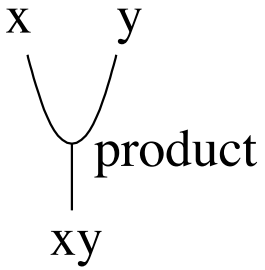
Equations of physics invariant under t to -t



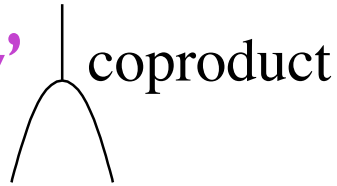
- Entropy is a construct
- Diagram shows electron-positron production at A, annihilation at B but could be read backwards
- Could read e+ as e- travelling back in time from B to A

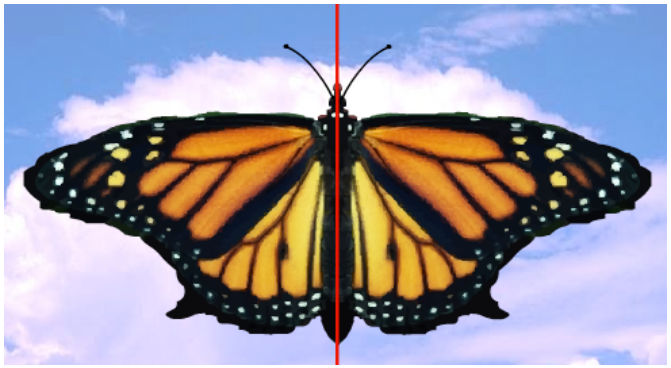
Quantum symmetry

An algebra takes two things and multiplies them



So we should also be able to `unmultiply'





Already implicit in the ancient greek notion of symmetry in `xerox map'

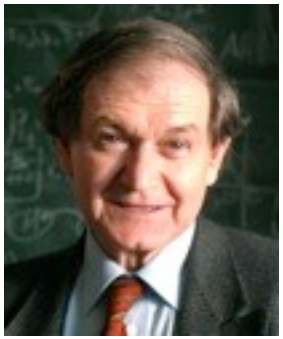
flip(x R y)= flip(x) R flip(y)

⇨ 1985-2000 concept of quantum symmetry as a `time reversible' object with both product and coproduct

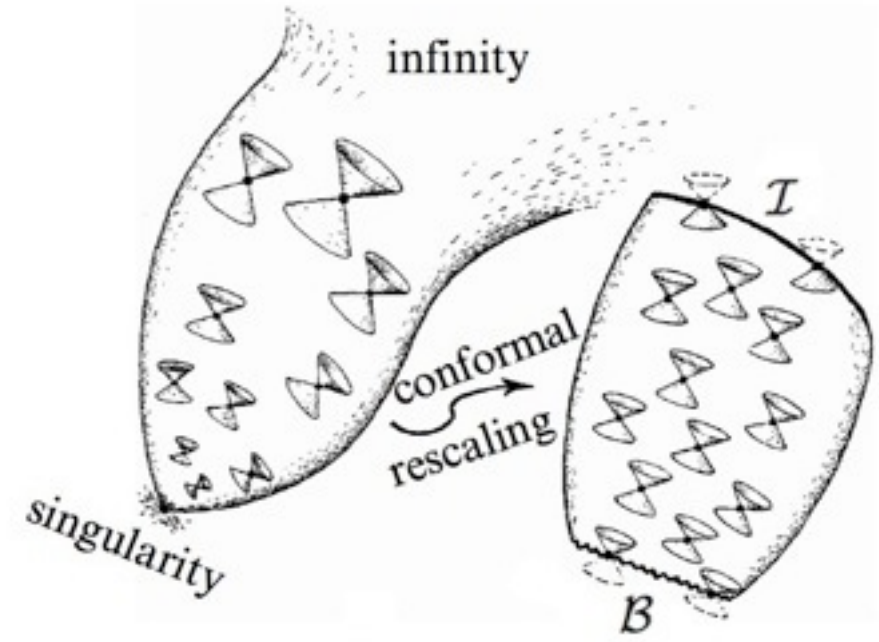
- Quantum spaces typically have such quantum symmetries

Applications knot theory & quantum computers

Before the big bang



Roger Penrose -



(from Penrose's chapter)

- Photons and gravitational waves experience no time and can carry information to ∞ future and from origin of Universe
- Such particles are blind to conformal rescalings that `stretch' spacetime but keep angles
- Use such rescalings to identify origin of Universe with ∞ future of *a previous universe*

⇨ Remnants of previous universe may be visible in ours