“*Not Even Wrong*”
The Strangest Ideas in Theoretical Physics

The Science of Spacetime:

A Physicists Guide to the Galaxy

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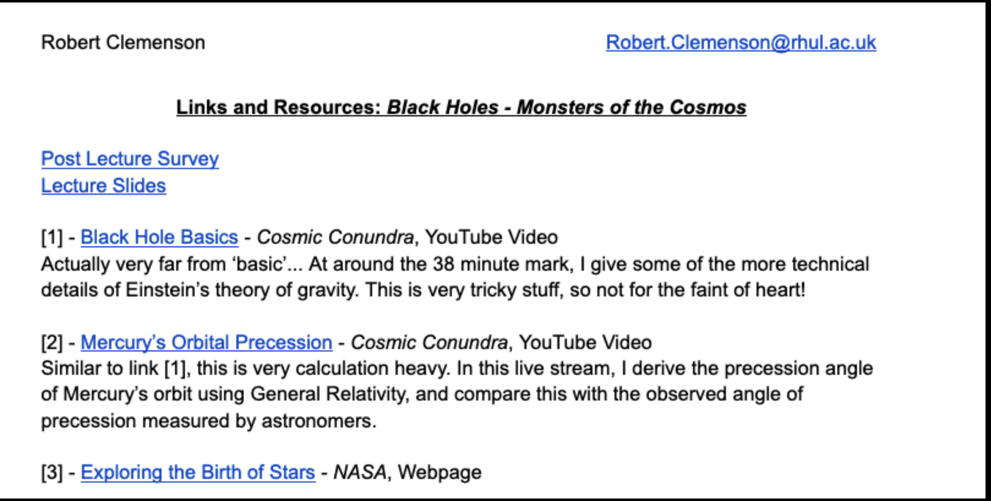
Southend Planetarium – 18.07.2026

Lecture Live Links (LLL)

Throughout the lecture, I will make a couple of references to previous talks, livestreams, and other online materials.

If you would like to check these out after the talk (or view recordings of previous lectures), please feel free to scan the QR code shown here.



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Links and Resources: *Black Holes - Monsters of the Cosmos*

Post Lecture Survey
Lecture Slides

[1] - Black Hole Basics - *Cosmic Conundra*, YouTube Video
Actually very far from 'basic'... At around the 38 minute mark, I give some of the more technical details of Einstein's theory of gravity. This is very tricky stuff, so not for the faint of heart!

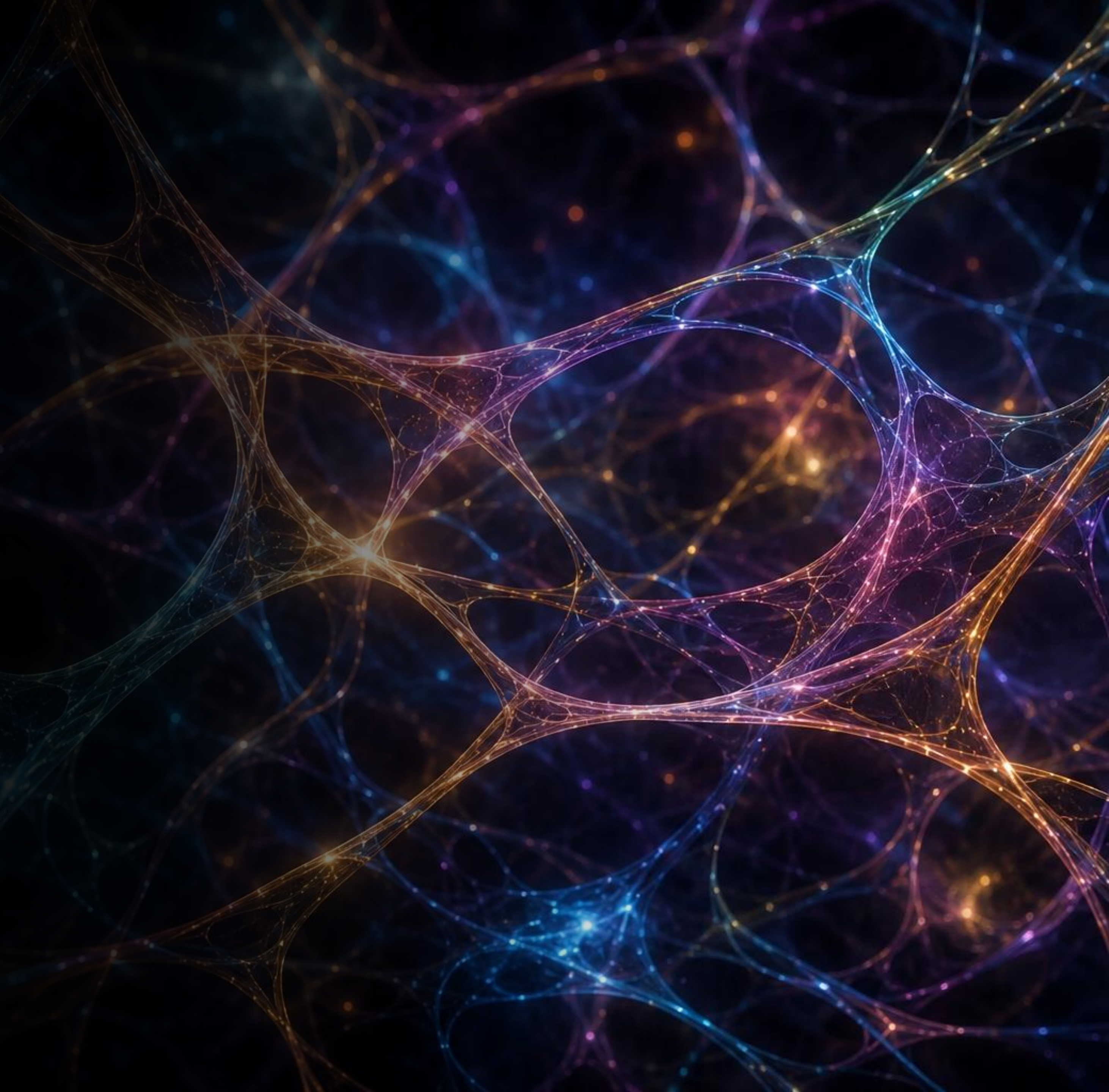
[2] - Mercury's Orbital Precession - *Cosmic Conundra*, YouTube Video
Similar to link [1], this is very calculation heavy. In this live stream, I derive the precession angle of Mercury's orbit using General Relativity, and compare this with the observed angle of precession measured by astronomers.

[3] - Exploring the Birth of Stars - *NASA*, Webpage

Scan the QR code above, or simply click the QR code in the PDF of the lecture slides.

Lecture Overview

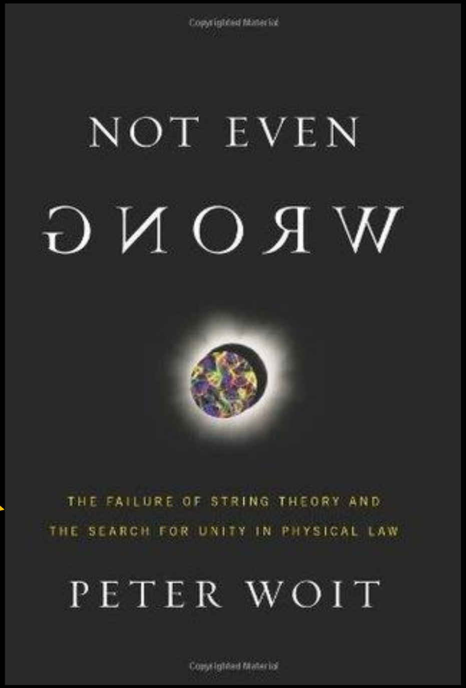
- *"Just a Theory"*
- Physics in the Fifth Dimension
- String Theory (Physics in the 11^{th} Dimension)
- Dark Energy
- The Multiverse
- Q&A (**Questions welcome throughout the talk!**)



“Not Even Wrong”

“**Das is nicht einmal falsch**”, Pauli exclaimed when asked about a paper by a physicist he did not rate. The English translation “it is not even wrong” has often been used as a put-down for theories without currently testable predictions.

There is a great book by Peter Woit, on the trials and tribulations of string theory. This is well worth a read!



Wolfgang Pauli, 1945.

Part I – “*Just a Theory*”

“Just a Theory”

‘Theory’ has a much stronger meaning in science than in our everyday parlance.

A scientific theory has some strong justification, be that:

1. Experimental proof, validating the theory until contrary evidence is found.

2. ‘Theoretical evidence’ that the theory fits into the framework

“Just a Theory”

1. Experimental proof, validating the theory until contrary evidence is found:

E.g. *Dawin’s theory of Evolution by Natural Selection* has abundant evidence that supports it.

If evidence contradicting the theory was found, we would have to reevaluate it (none has even been presented).

“Just a Theory”

2. ‘Theoretical evidence’ that the theory fits into the framework of existing knowledge:

E.g. *String Theory* – the idea that all matter, at its most fundamental level is composed of vibrating strings.

This might sound like a bizarre and baseless guess… However, string theory has strong ‘***theoretical evidence***’, in that it builds upon deep and well tested concepts in physics. This does not mean that string theory is correct, but it does elevate it beyond a baseless guess.

“Sort of True”

“Absolute truth” is a challenging concept, and not one we grapple with in the sciences.

Science deals with *models*; a description of a physical system that allows us to understand *some* aspects of the phenomena and make testable predictions. This does not mean that the model has to work in *all circumstances*.

For example: Newton’s theory of gravity, vs Einstein’s theory of gravity…

“Sort of True”

Newton’s theory of gravity allows us to (mostly) explain the orbits of planets in our solar system, and the dynamics of our galaxy. Newton’s theory allowed us to get to the moon.

Einstein’s theory of gravity (General Relativity) predicts the existence of black holes, and solves subtle problems related to the orbit of the planets that Newton’s theory cannot explain.

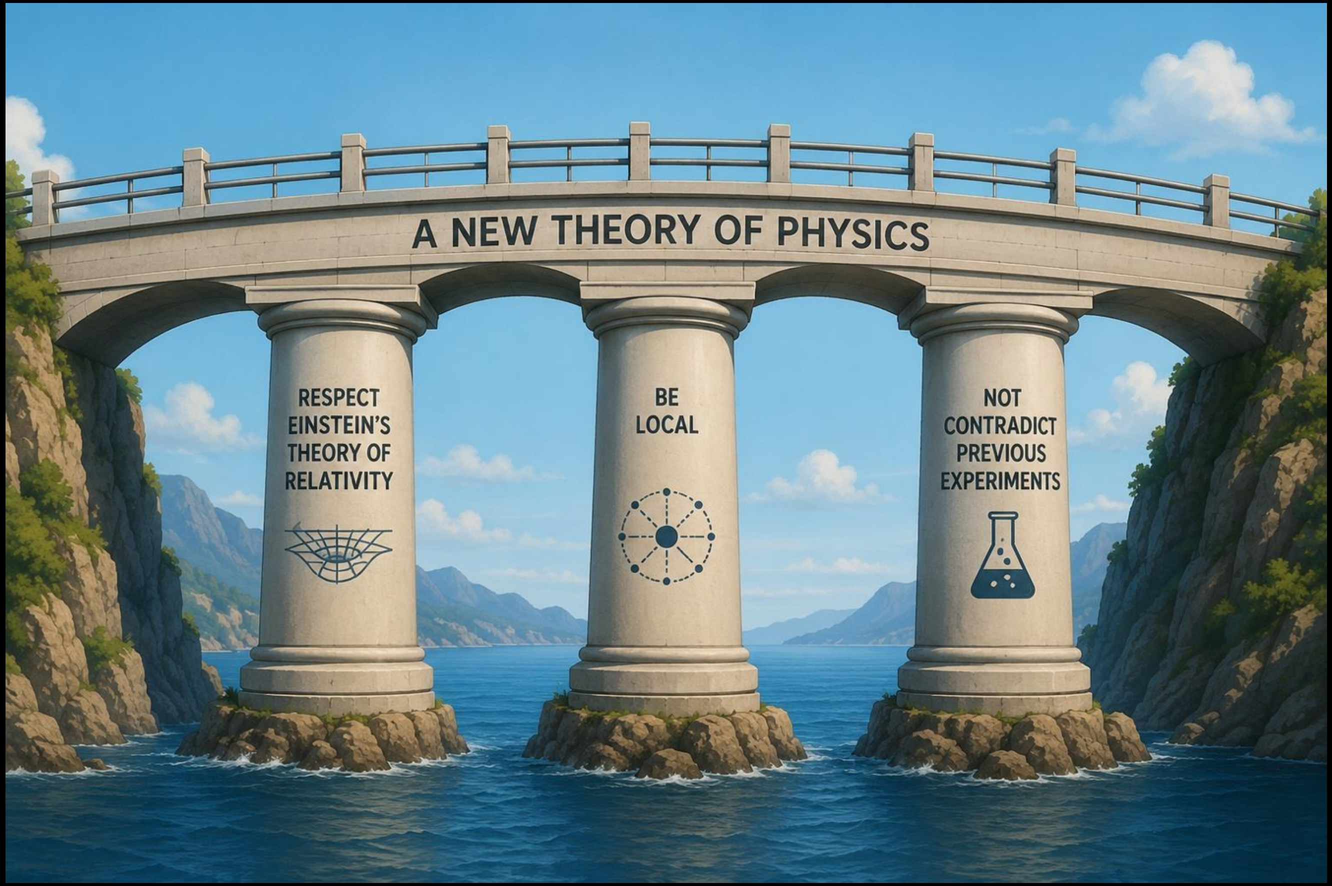
Newton’s theory works for (relatively) small masses. Einstein’s theory picks up where Newton’s left off, and tells us more about larger masses and subtle (harder to observe) effects.

Touchstones

There are some principles, so well tested, we expect that any new theory of physics we write down should not violate these principles.

A prospective physics theory should:

- Respect Einstein's theory of relativity (specifically, general covariance).
- Be Local.
- Not contradict previous experimentally tested results.



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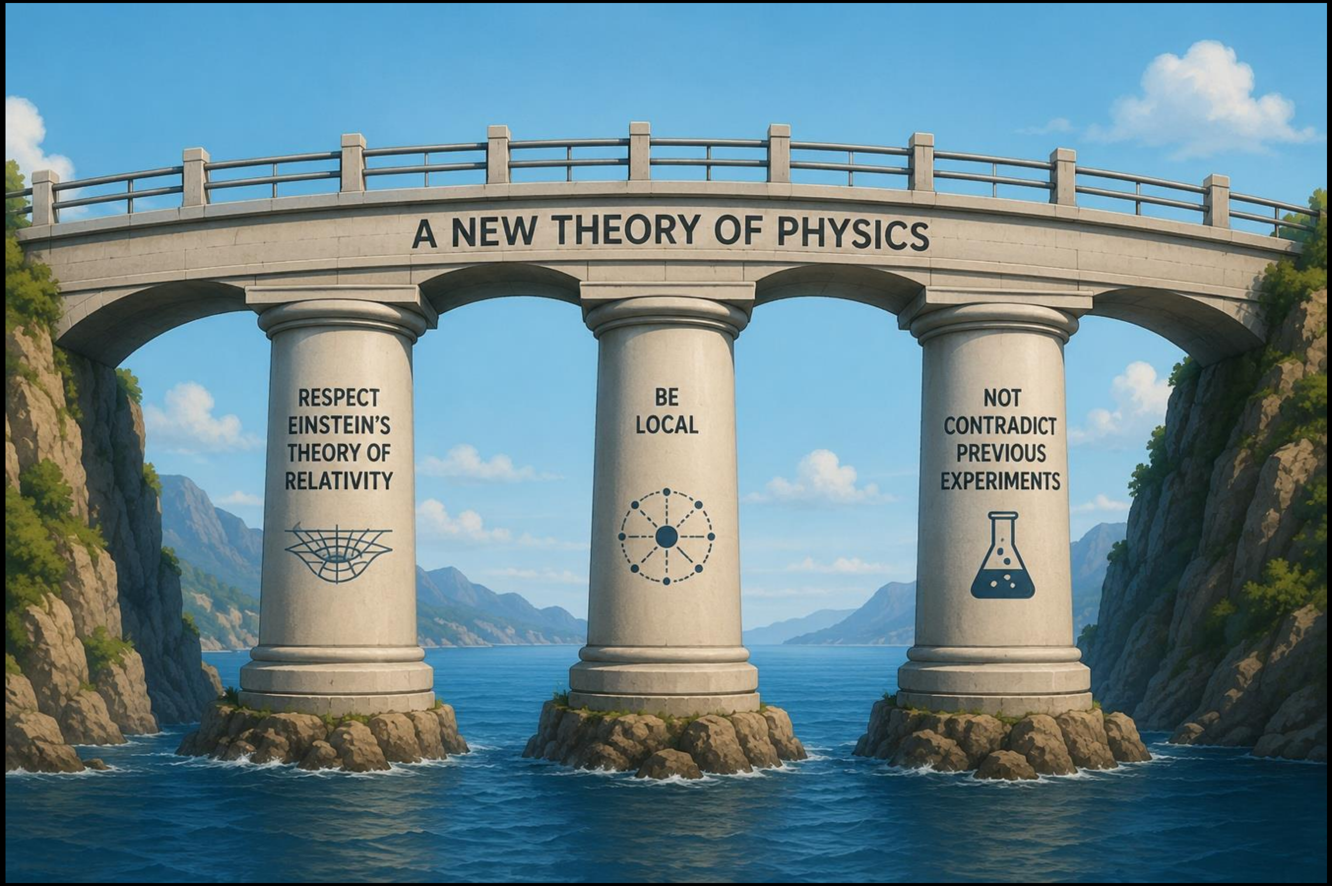


Ideally... A new theory should also be **simple** and **beautiful**.

*This is a wish, rather than a requirement!

Part II – Physics in the Fifth Dimension

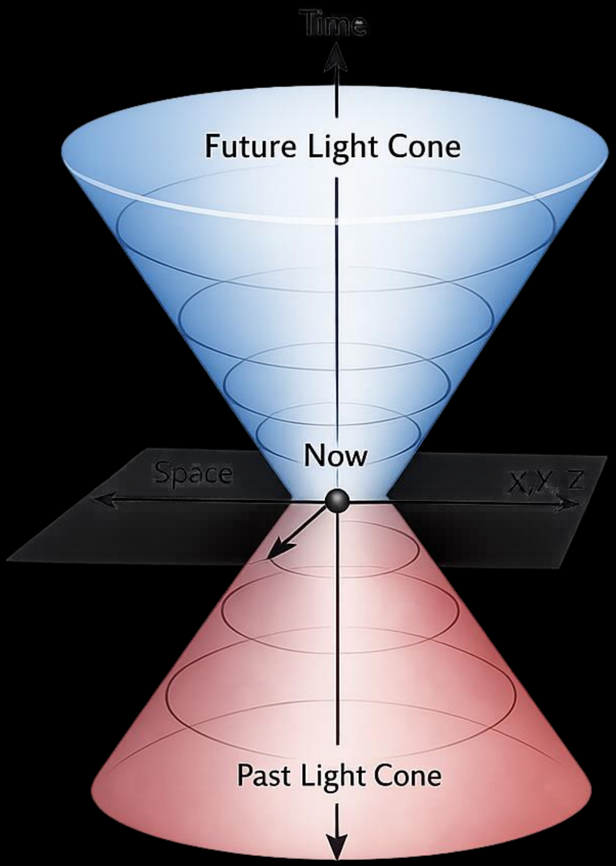
Einstein in 4D - 1908

A few years after Einstein publishes his theory of space, time, and light (Special Relativity), Herman Minkowski realizes that Einstein's theory of relativity can be simplified if space and time are unified into a single geometric framework…

Spacetime

The three dimensions of space, and one dimension of time combine to form a four-dimensional spacetime continuum.

This geometric insight is what allows Einstein to figure out his theory of gravity several years later.



Hermann Minkowski, early 1900's.

Einstein in 5D - 1921

In 1921, Theodor Kaluza makes an astonishing discovery…

If you add an extra space dimension to Einstein’s Theory of gravity, you get the theory of Electromagnetism FOR FREE.

Two seemingly separate theories, about separate phenomena now appear to be two sides of the same 5D coin…

Theodor Kaluza, early 1900’s.

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Our Universe is not 5D!

Or is it.....

Einstein in 5D - 1926

The apparently missing space dimension considered by Kaluza, would appear to relegate his 5D theory of gravity & electromagnetism to the scrapheap of ‘neat but useless’ ideas.

However, in 1926, Oskar Klein figured out a way that this extra space dimension might *really* be present in our Universe....

Oskar Klein, approx 1930.

Einstein in 5D - 1926

Klein realized that Kaluza's theory still works, even if this extra space dimension is *curled up* (compactified) very small.

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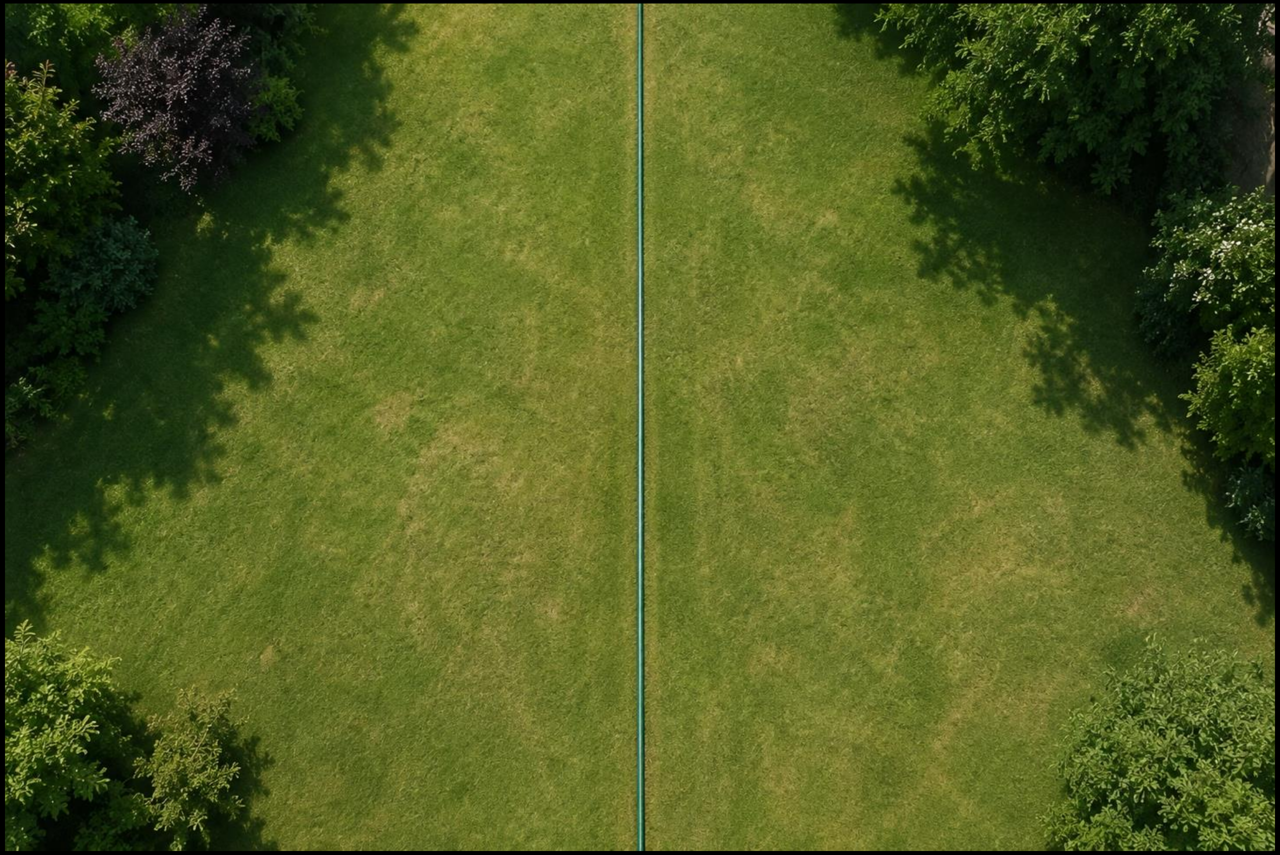

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Analogously… The Extra Dimension proposed by Kaluza, and compactified by Klein would be unobservably small to us – yet would still have consequences for the laws of physics in our Universe.

Kaluza-Klein Theory

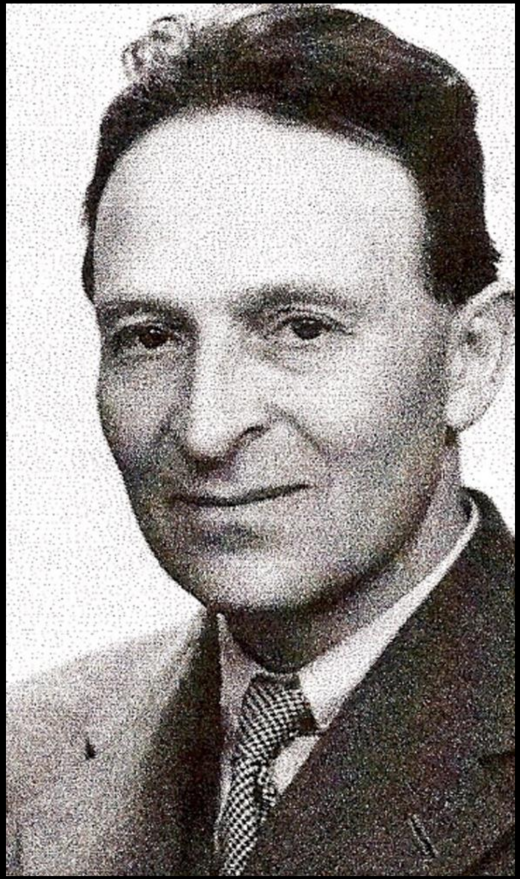
The work of Kaluza and Klein on this 5D model of the Universe is abbreviated as the 'Kaluza-Klein theory'.

Interest in Kaluza-Klein theory quickly faded in the 1930's.

It isn't a quantum theory (which was all the rage in the 30's), and it also predicts the existence of an additional field not observed in nature.

However… This is not the end for Extra Dimensions.

Theodor Kaluza, early 1900's.

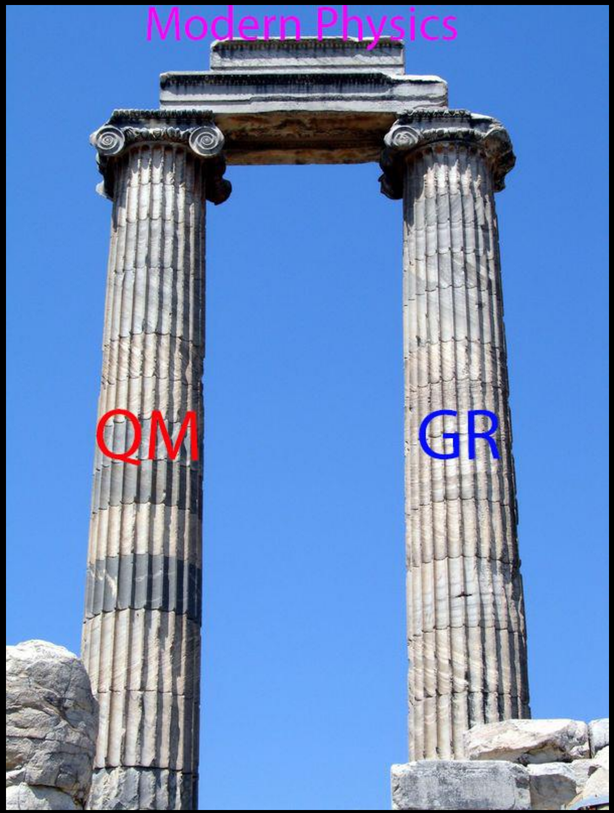


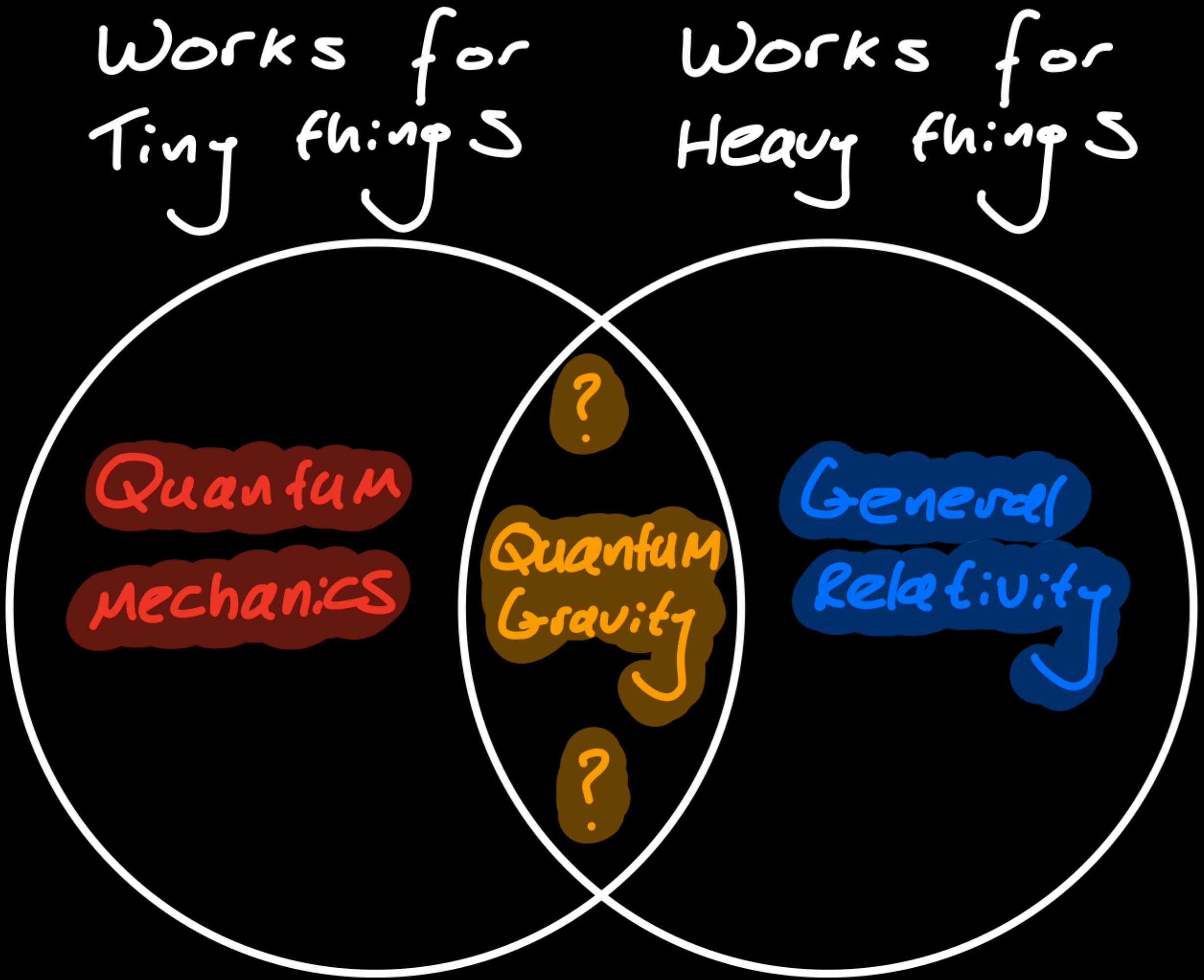
Oskar Klein, approx 1930.

Part III – String Theory

Quantum Gravity

A quantum theory of gravity would unify the two major theories of 20th century physics: Quantum Mechanics, and General Relativity (Einstein's theory of gravity).





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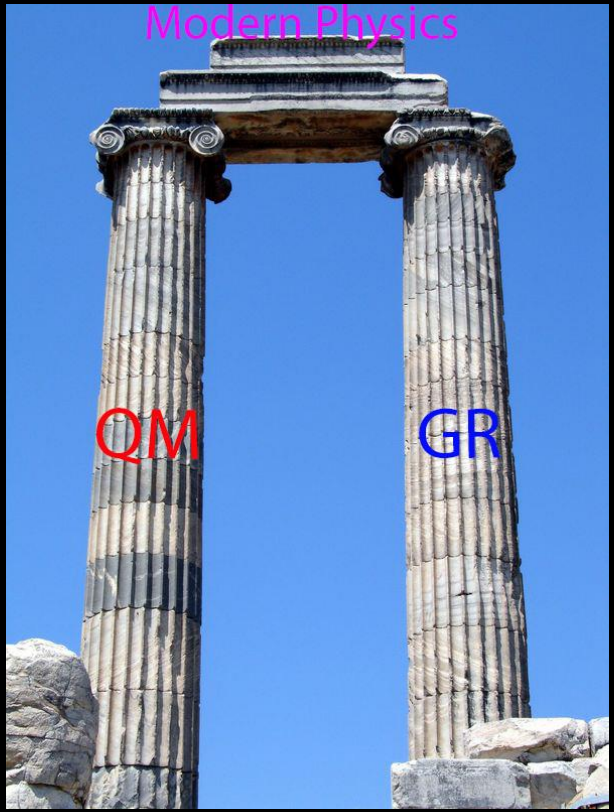
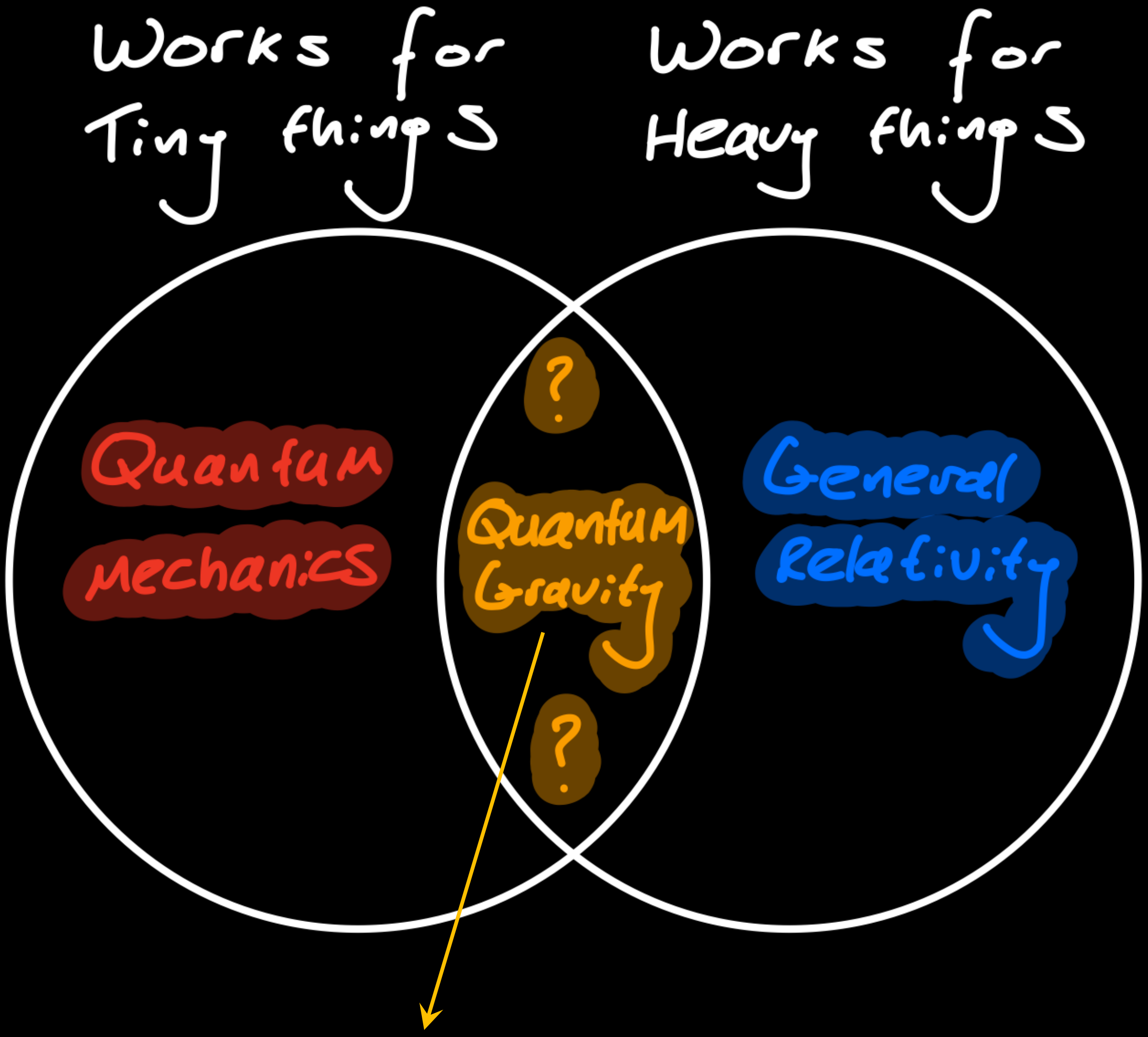




Possibly String Theory...

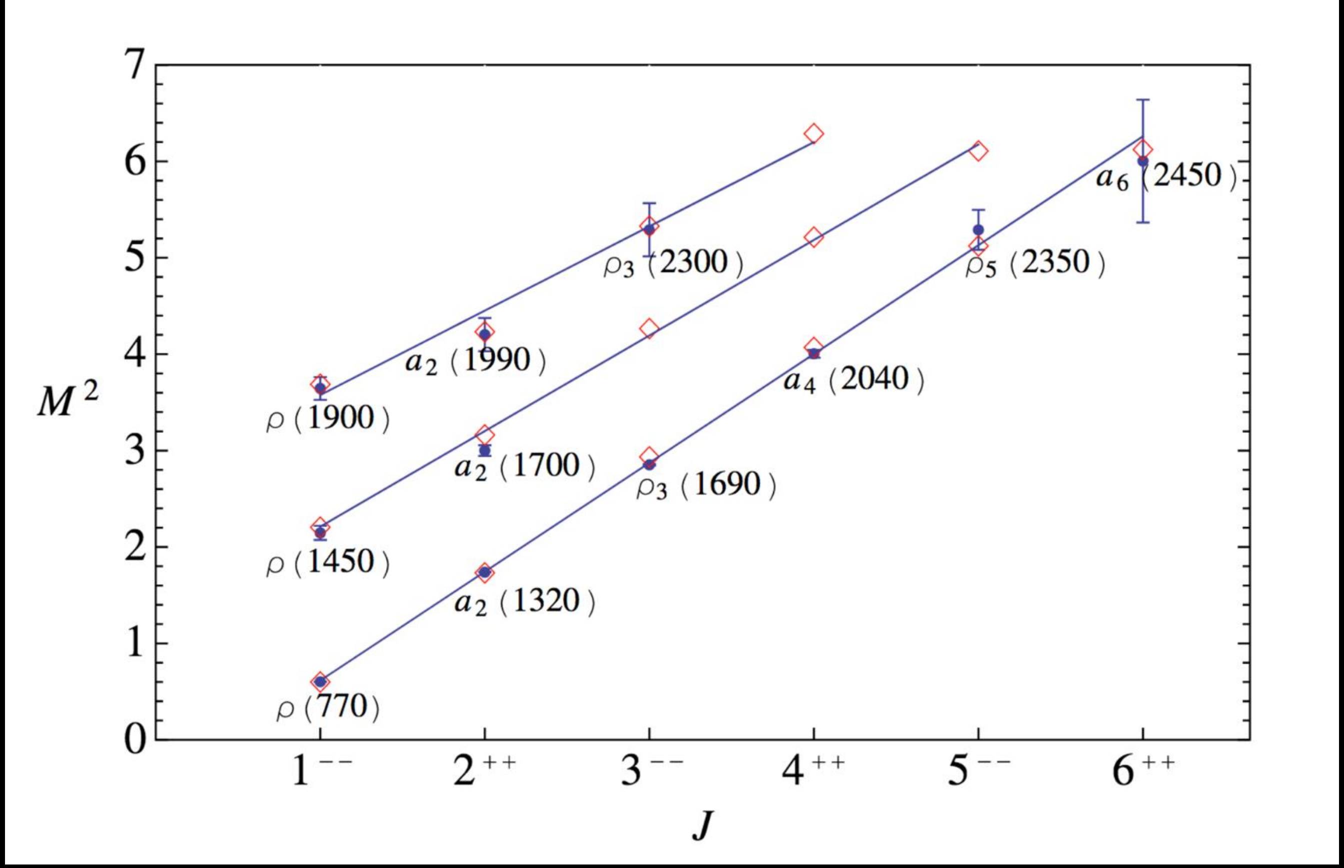
Stringy Origins

The origin of String Theory actually has nothing to do with gravity.

Physicists in the 1950/60’s were drowning in newly discovered particles.

“*The finder of a new elementary particle used to be rewarded by a Nobel Prize, but such a discovery now ought to be punished by a $10,000 fine*” – Willis Lamb

In 1959, Tullio Regge notices that Hadrons tend to appear along straight lines when plotted on a graph of mass-squared, against total spin.



Regge trajectories for a selection of Mesons (particles we now understand to be made out of a pair of quarks).

Stringy Origins

In 1968, Gabriele Veneziano took a distinctly ‘non-physics’ approach, to try and explain the tower of Hadrons with different masses and spins.

He identified the mathematical properties this function should have, and surfed through textbooks of mathematical functions to find one that fit the bill.

Remarkably, he found what he was looking for in the *Euler-Beta Function*, a function introduced nearly 250 years earlier by Leonhard Euler.

This formula (the ‘Veneziano Amplitude’) also reproduced the shape of the Regge trajectories we saw previously.

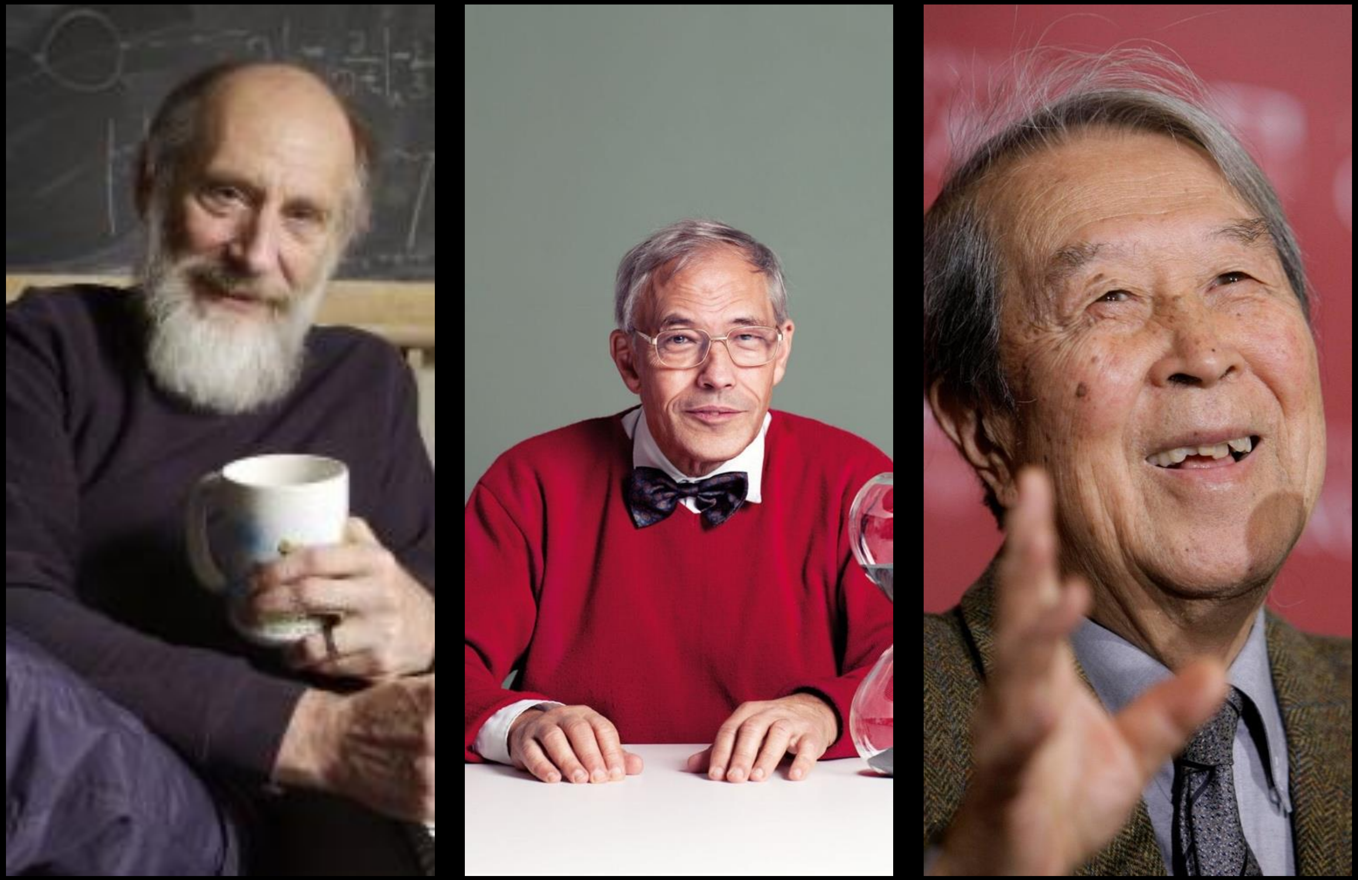
Gabrielle Veneziano, 1960’s.

Stringy Origins

At this point, Veneziano's formula is still just a shot in the dark (albeit a very successful one!).

Next, physicists wanted to understand what physical model this abstract formula implies.

Between 1969 and 1970, the interpretation of Veneziano's formula was independently discovered by Susskind, Nielsen, and Nambu.



(Left to Right) Leonard Susskind, Holger Bech Nielsen, Yoichiro Nambu.

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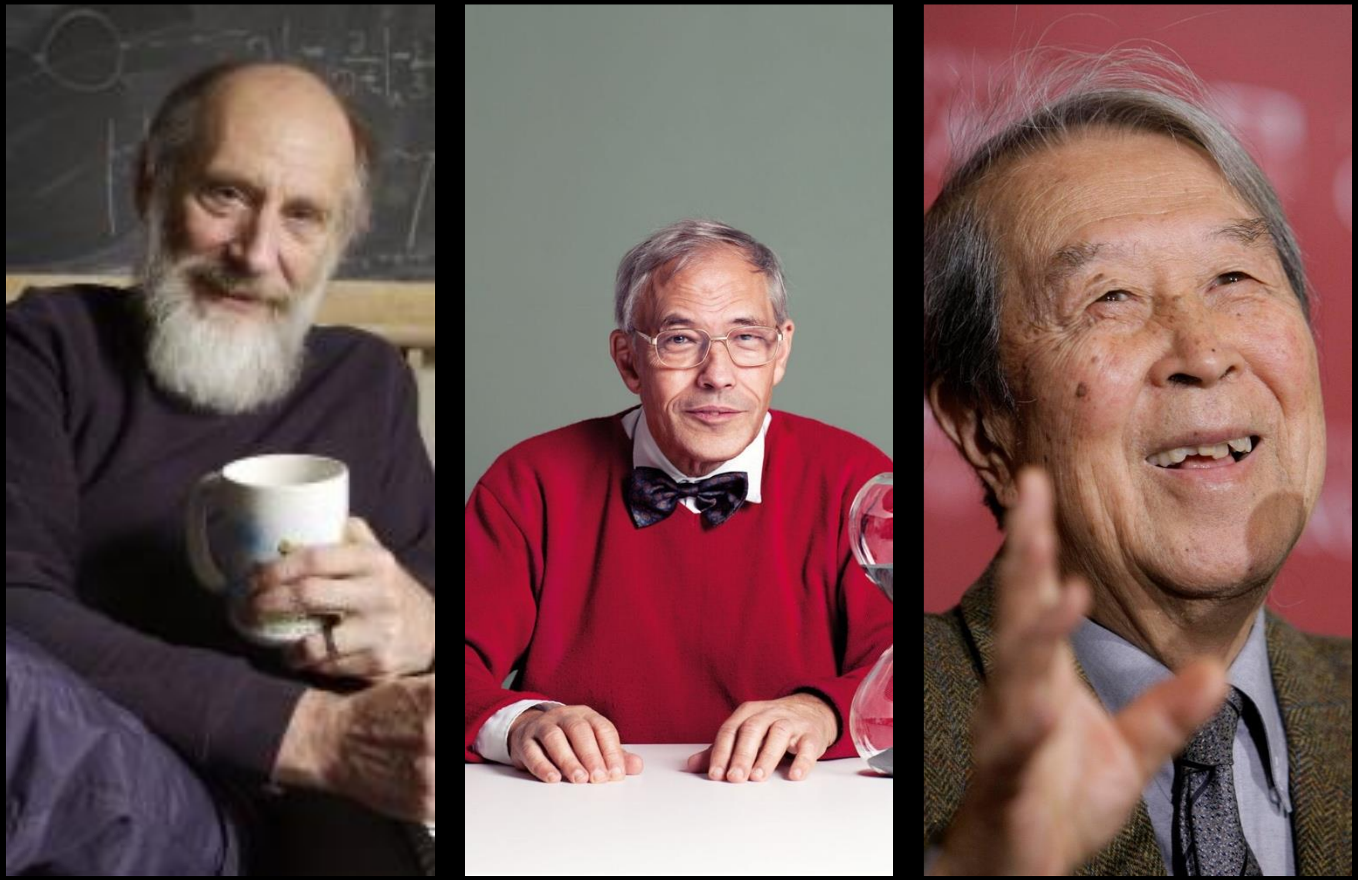

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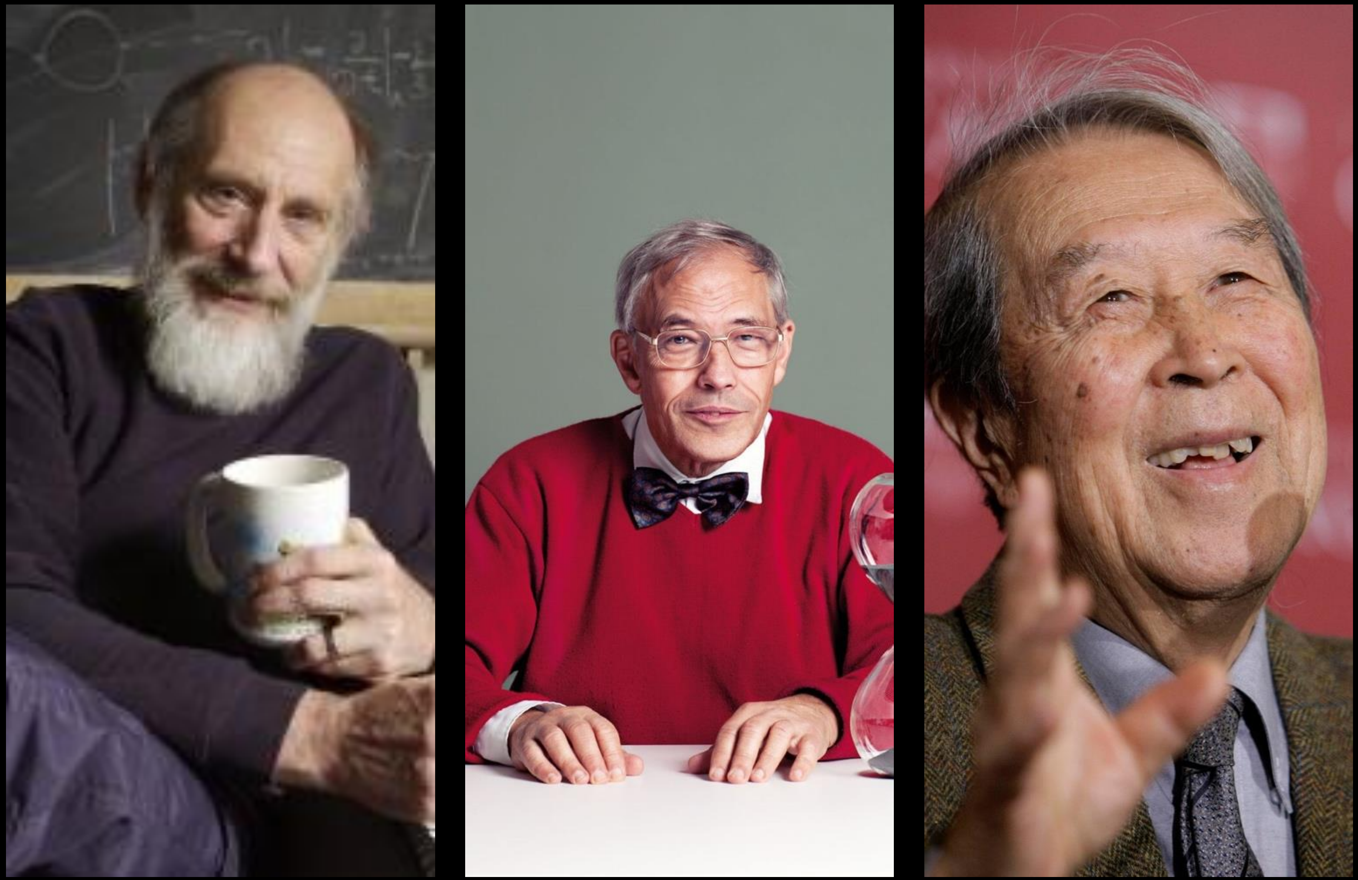
The Answer….

Strings!



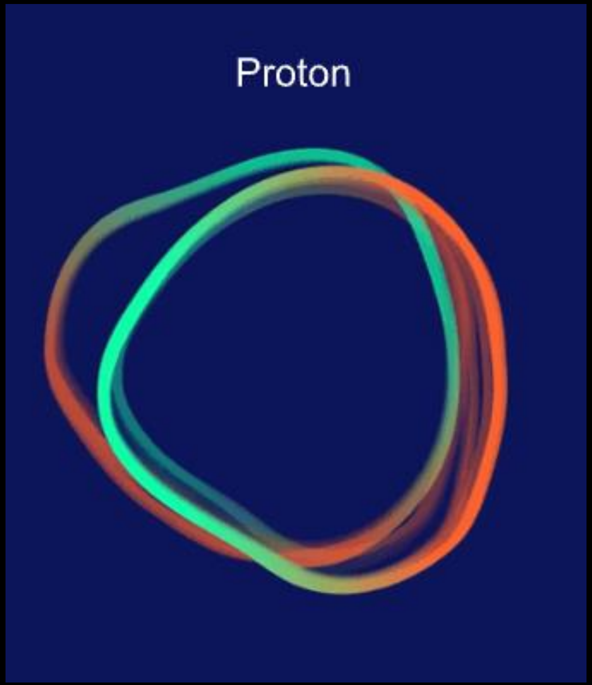
(Left to Right) Leonard Susskind, Holger Bech Nielsen, Yoichiro Nambu.

Stringy Origins

The interpretation of Veneziano's formula suggests:

All matter, at its most basic level, is composed of vibrating fundamental strings; with different particles emerging as different modes of vibration.

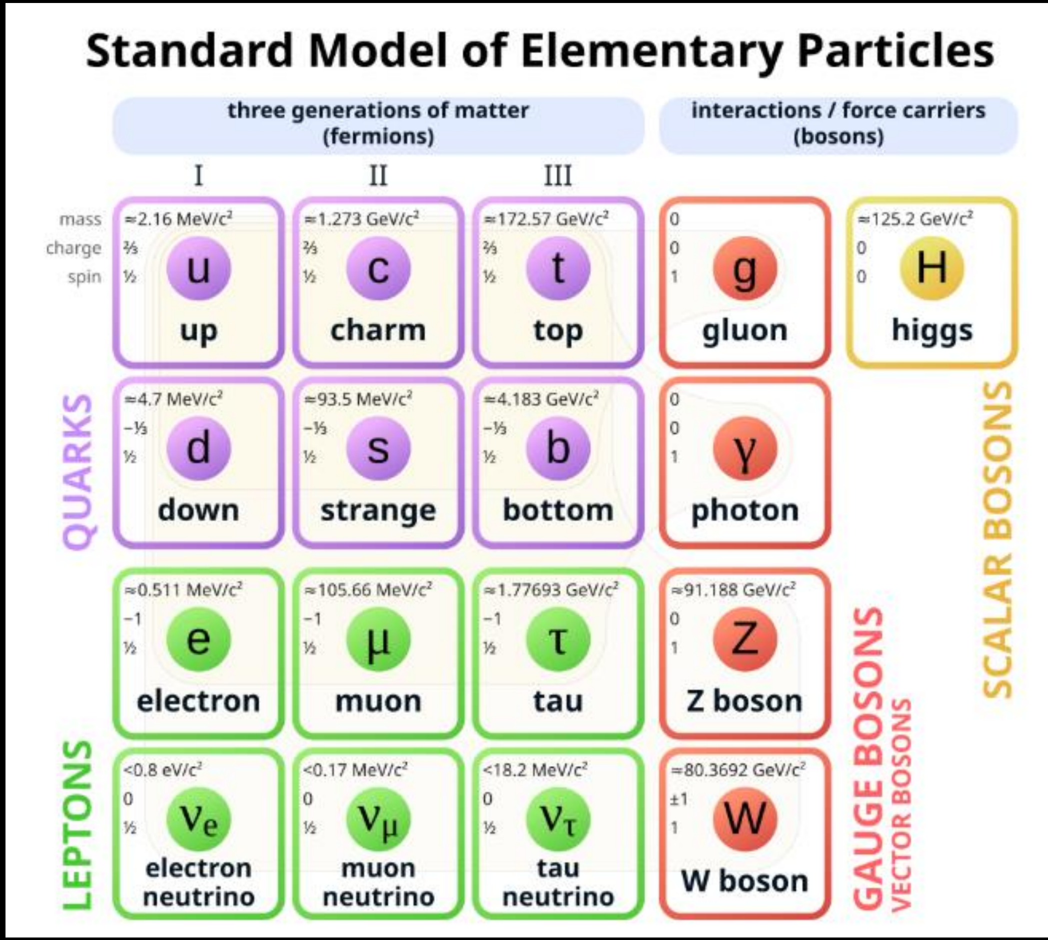
A bizarre, and remarkable hypothesis…



Gravity for Free!

Around the same time that Susskind, Nielsen, and Nambu were interpreting the stringy nature of Veneziano's formula; an additional particle was uncovered from the mathematics.

This particle has no mass, and has a spin of 2.



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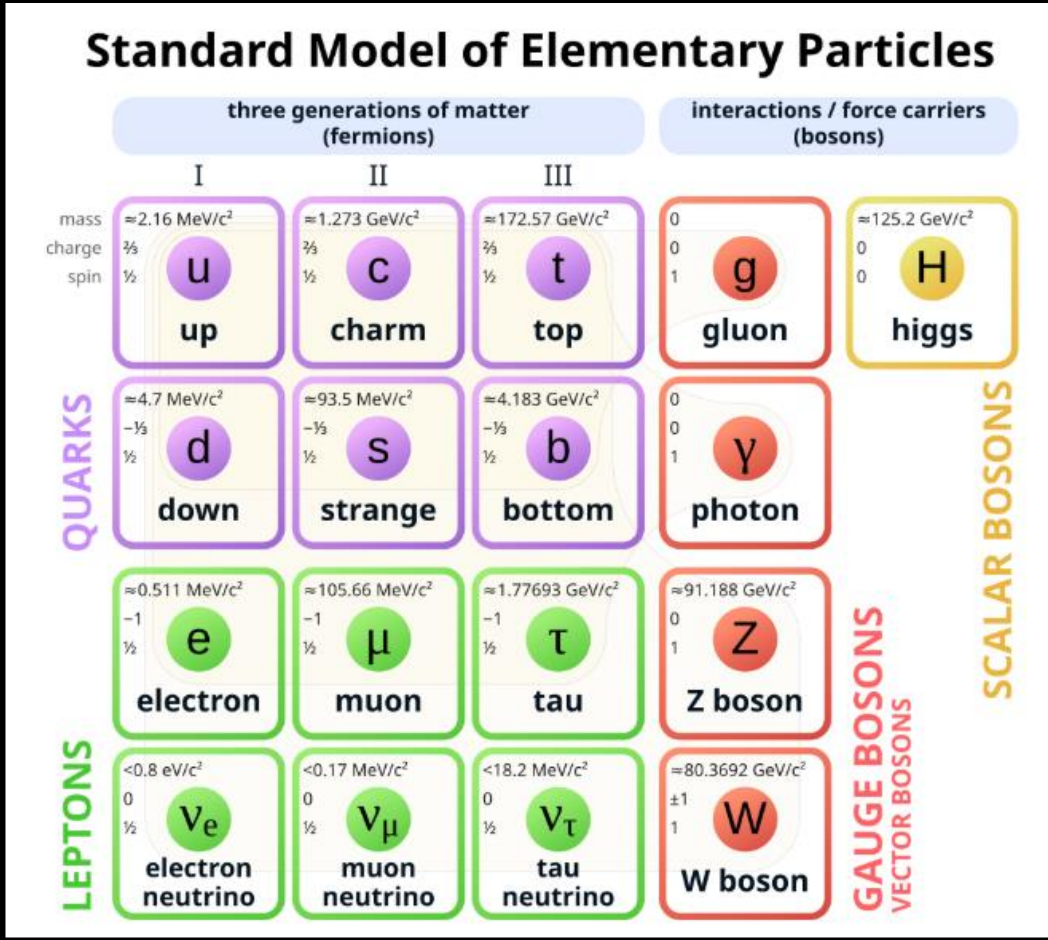

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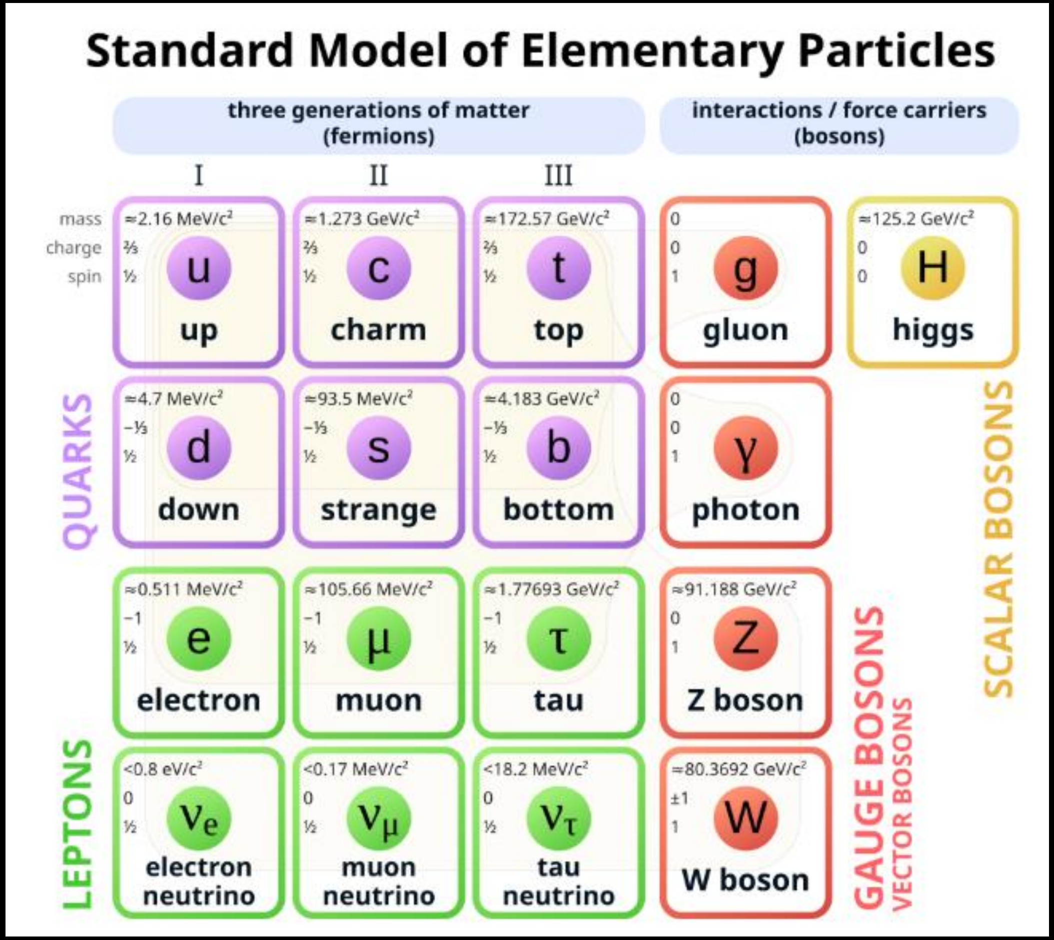
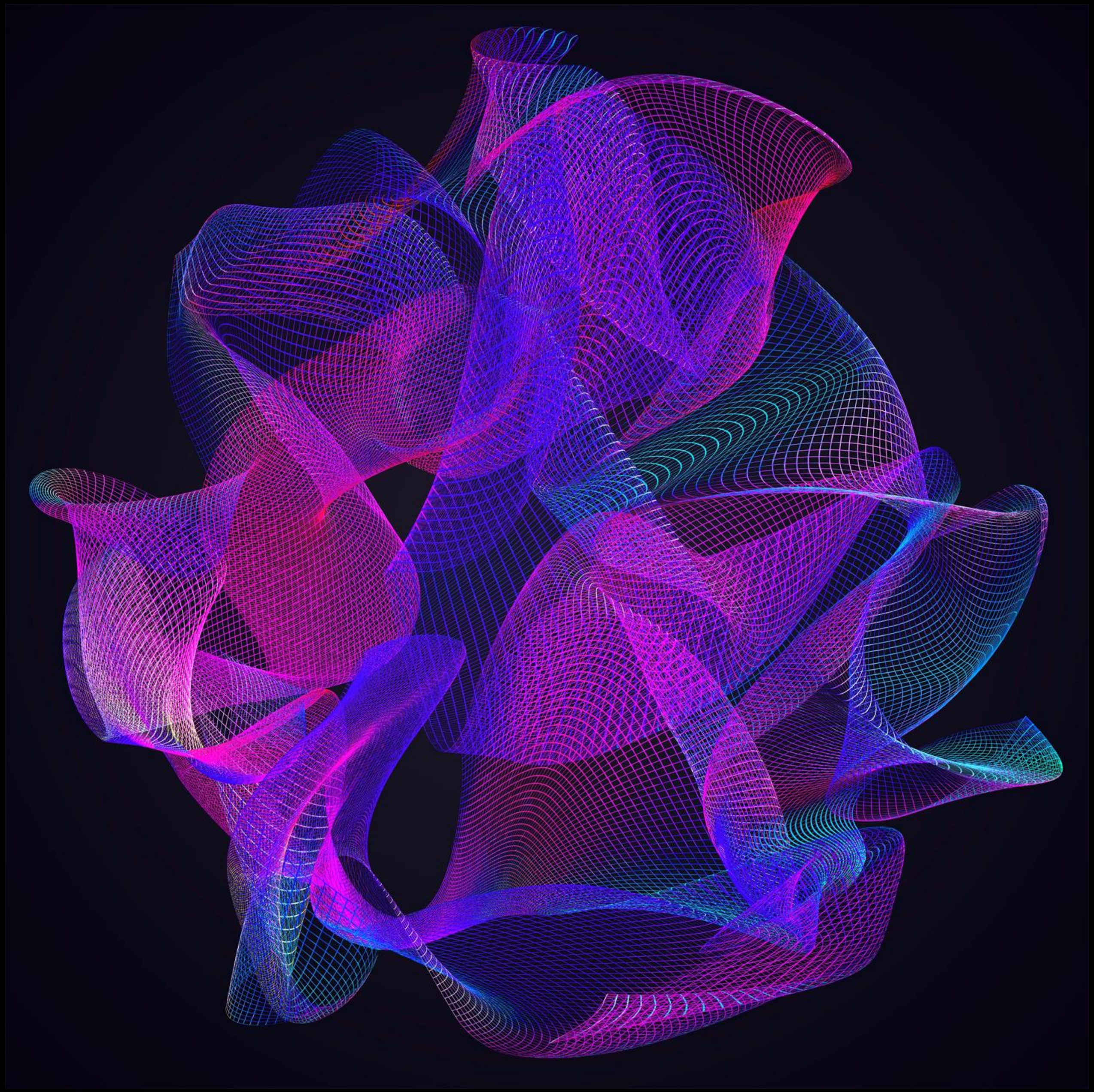
String theory has provided us with a new route to Einstein's theory of gravity!



Extra Dimensions

As wonderful as this sounds… String Theory in the early 1970's is far from perfect. The theory has a number of pathologies, including the presence of 'ghosts' (particles with negative energy).

In 1973, Peter Goddard, Jeffrey Goldstone, Claudio Rebbi, and Charles Thorn (GGRT) discover a work around…



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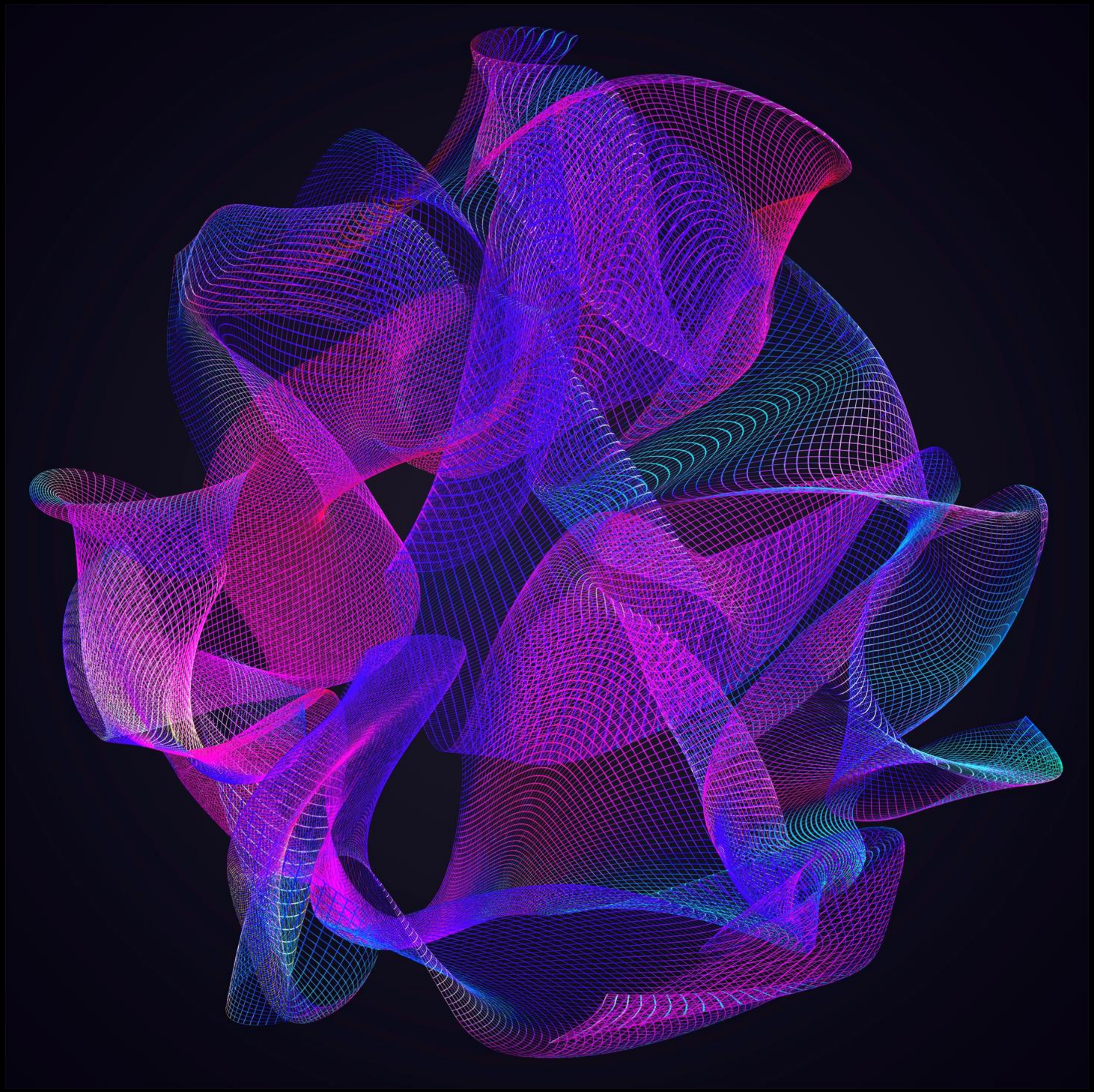
The various pathologies in string theory can be removed, if spacetime has **26 dimensions**!



Let’s Pause…

What did we do?

- Attempt to explain the masses or a family of particles.
- Assert well established principles, like relativity and quantum theory.

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- Subatomic vibrating strings…
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What did we do?

- Attempt to explain the masses or a family of particles.
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- Subatomic vibrating strings...
- ~~26 Spacetime Dimensions...~~
- In the 1980's the required number of dimensions is reduced to 10.

Quantum Gravity?

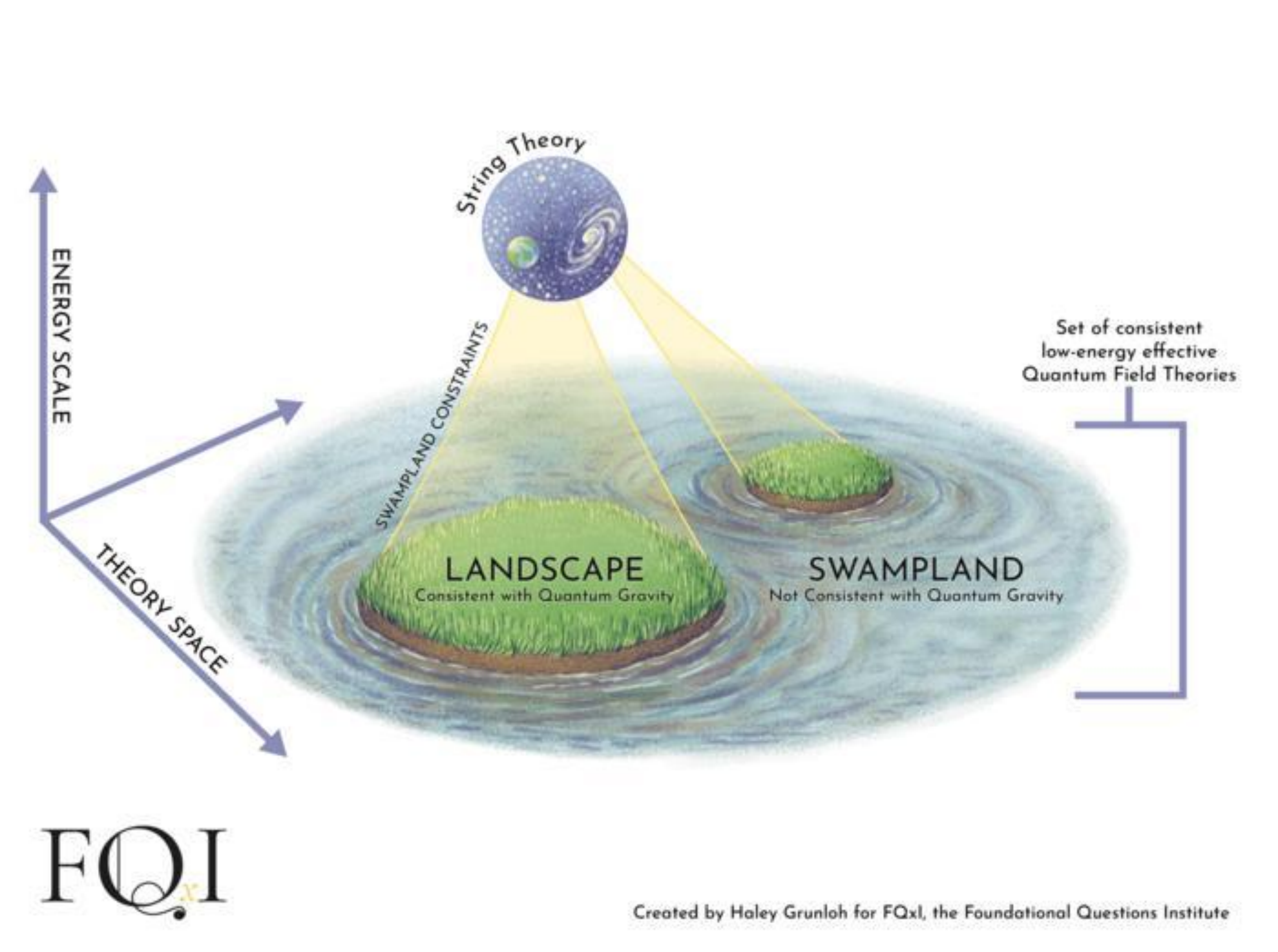
String theory is without a doubt, the closest we have come to a quantum theory of gravity.

It does not suffer many of the flaws that other attempts have.

However, there are problems with string theory…

1. The String Landscape

2. No Testable Predictions



Part IV – Dark Energy

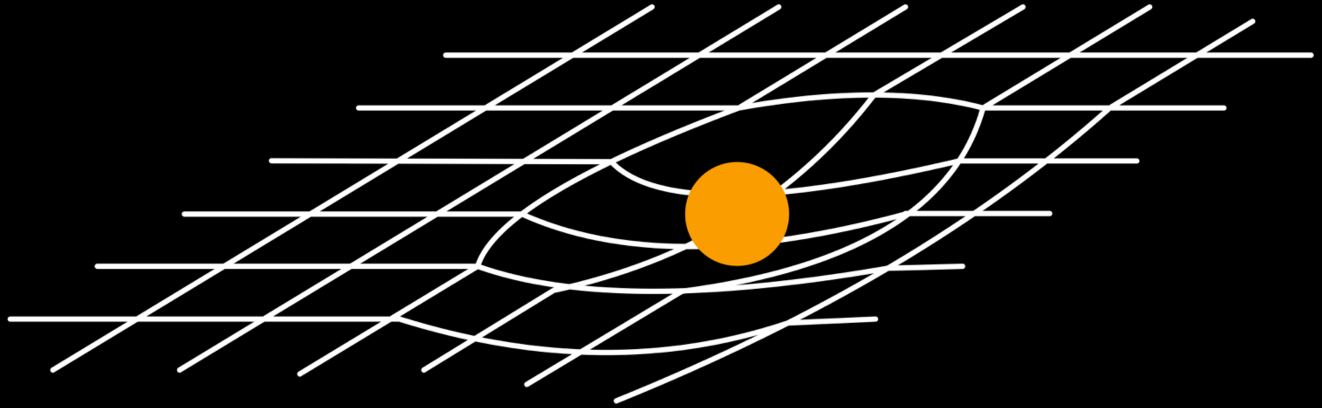
General Relativity

The presence of matter, causes space-time to curves.

The curvature of space-time cases matter to experience the illusion of a gravitational force.

'Spacetime tells matter how to move; matter tells spacetime how to curve.' – John Wheeler

Space-time is more than just the stage on which physics happens, they are players too.



$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

Space-time Curvature

Speed of Light

Matter

The Big Bang Theory (no.. not that one…)

In 1922, Alexander Friedmann published his equations for calculating the changing size of the Universe.

His equations (now called 'The Friedmann Equations') spring from Einstein's theory of gravity (general relativity), published seven years prior.

Pi: 1900 BC Ancient Babylon

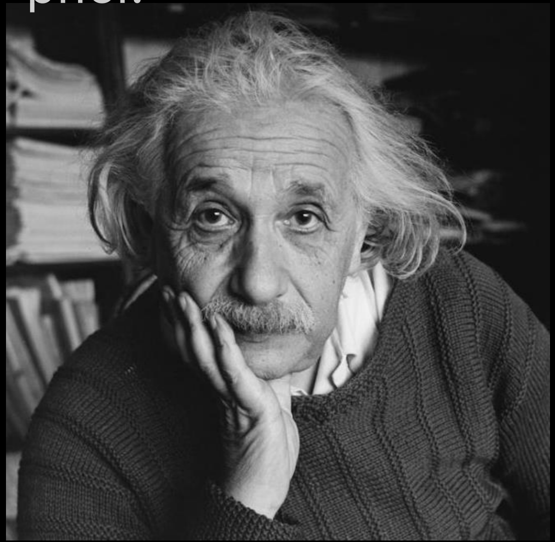
Newton's Gravitational constant: 17th century England

The speed of light: 17th century Denmark

$$H^2 = \frac{8\pi G}{3}\rho - \frac{kc^2}{a^2} + \frac{\Lambda c^2}{3}$$

Density of Matter in the Universe

Einstein's "Cosmological constant"



Albert Einstein circa 1950

Alexander Friedmann circa 1920

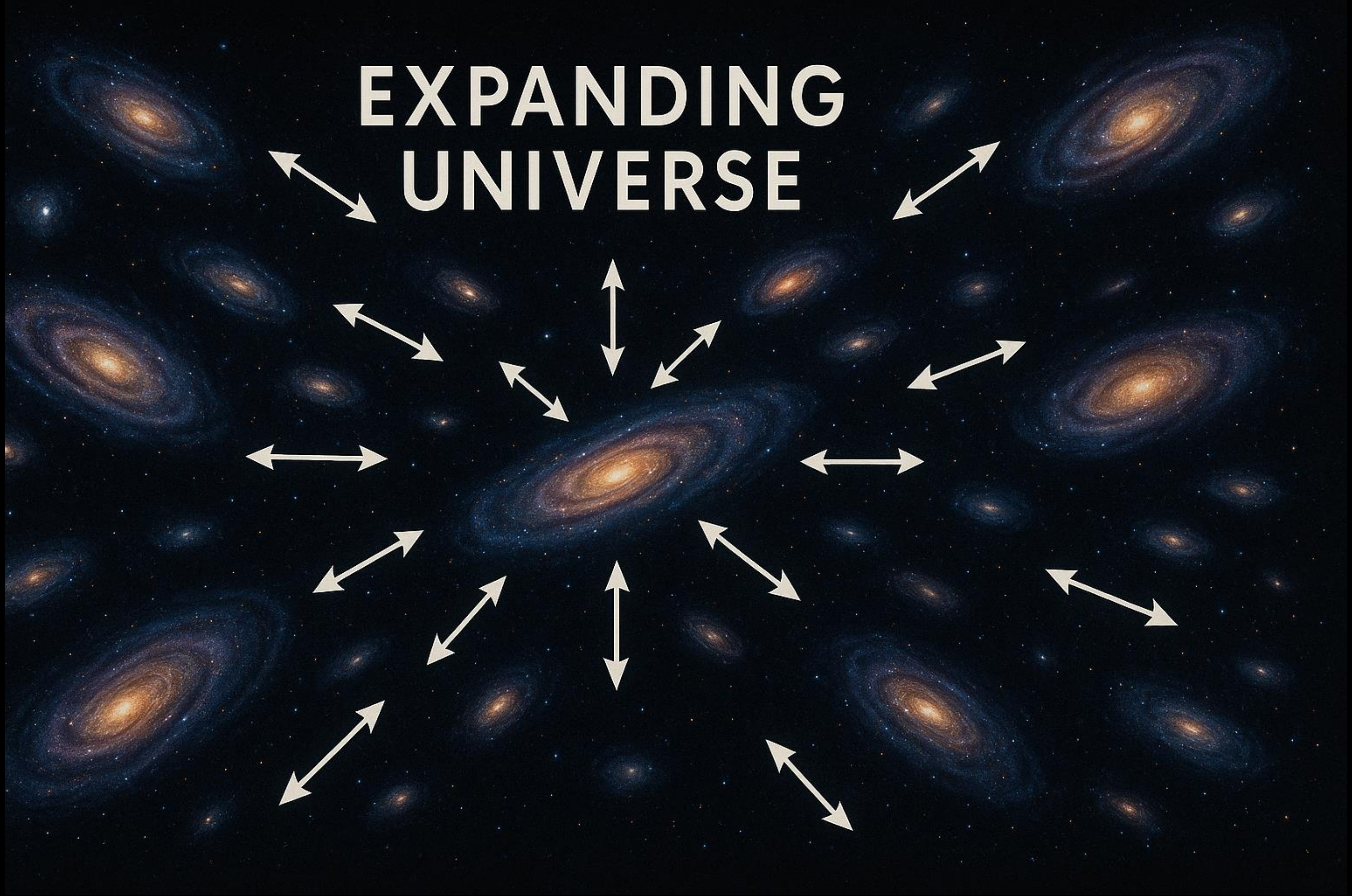
We will return to the Cosmological Constant later…

The Big Bang Theory (no.. not that one...)

Friedmann's equation shows us that it is possible that the Universe could change in size.

This was puzzling, as the prevailing scientific theory in the 1920's was the so called 'Steady State Theory'.

Fred Hoyle circa 1955



In an expanding Universe, every galaxy moves away from every other galaxy (on average..). There is no common center to the expansion.

So... Is the Universe expanding or not?

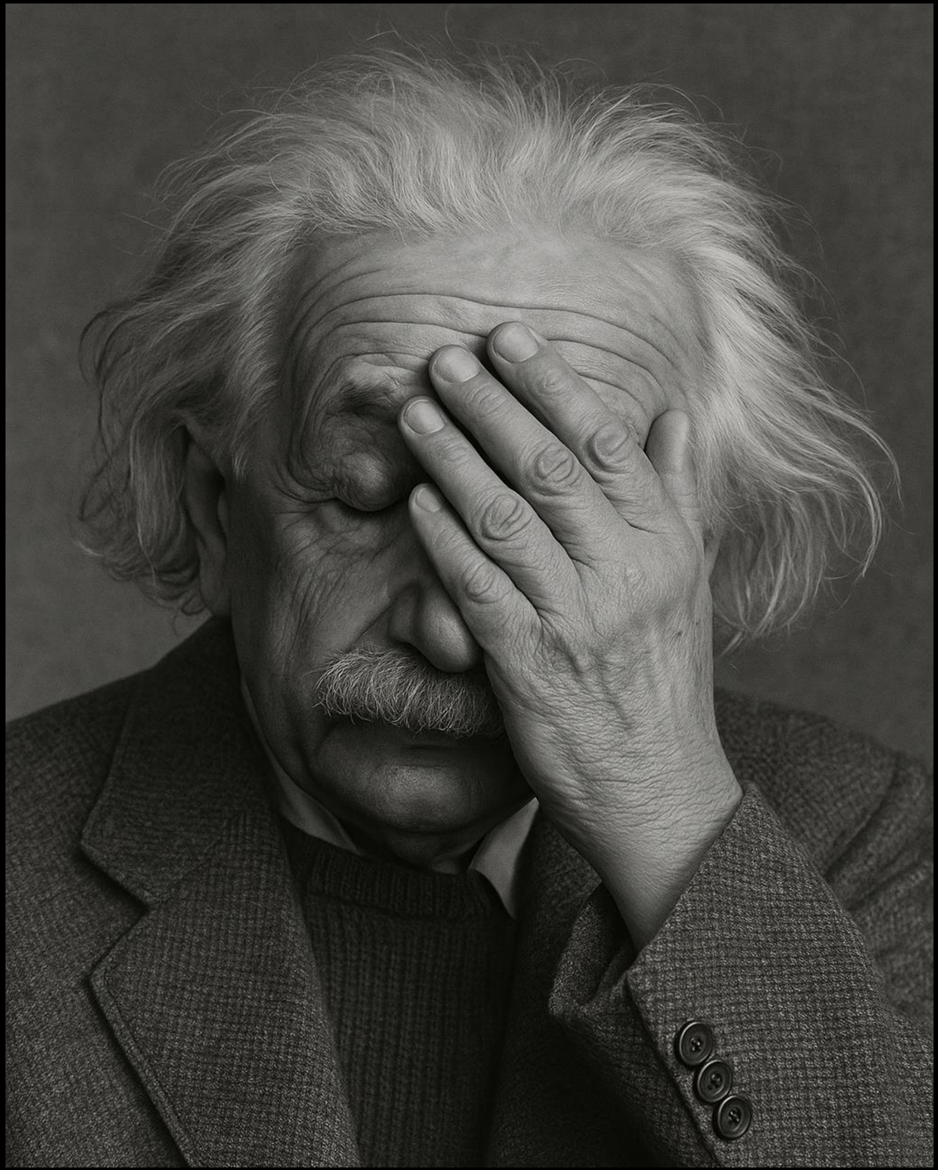
The Big Bang Theory (no.. not that one...)

The belief that the Universe is static in size first led Einstein to add a 'Cosmological Constant' into his equations of gravity.

This term acts to increase the density of energy in the Universe, to pull the galaxies back together and stop them from expanding away from one another.

He would later refer to his invention of this constant as his "biggest blunder".

But was Einstein completely wrong?.... We will see shortly...



Note: This is an AI generated image.

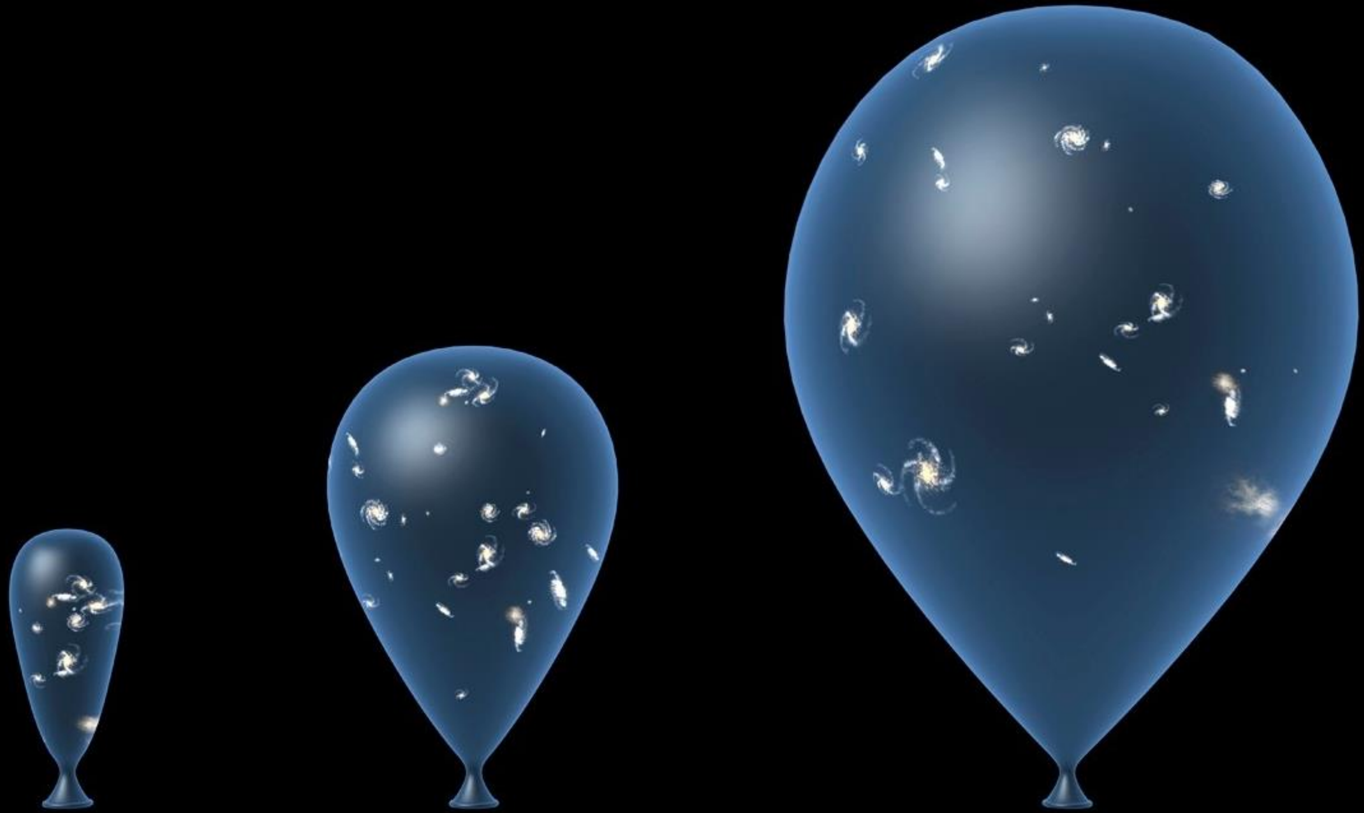
The Big Bang Theory (no.. not that one...)

In 1929, Edwin Hubble publishes his observations that distant galaxies are moving away from us, with the more distant galaxies moving away at higher speeds.

In 1931, Georges Lemaître proposes that the Universe might have begun from a single point that he called 'the primeval atom'.

Georges Lemaître circa 1930

Edwin Hubbe circa 1930

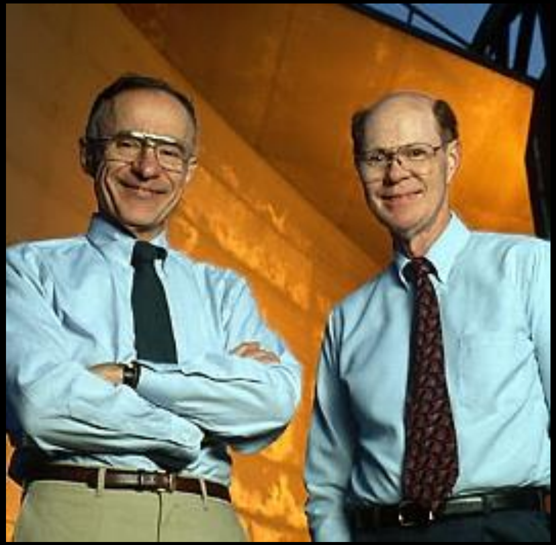


In an expanding Universe, every galaxy moves away from every other galaxy, like points on an expanding balloon. There is no common center to the expansion.

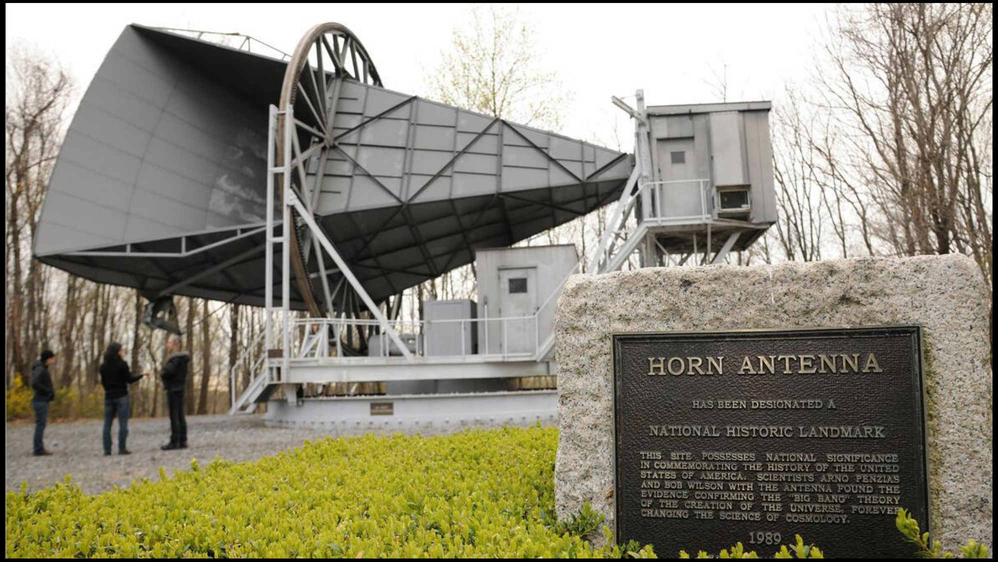
The Big Bang Theory (no.. not that one…)

In 1964, Penzias & Wilson discovered (accidentally) a background of microwave radiation, that could only be due to a hot BIG BANG.

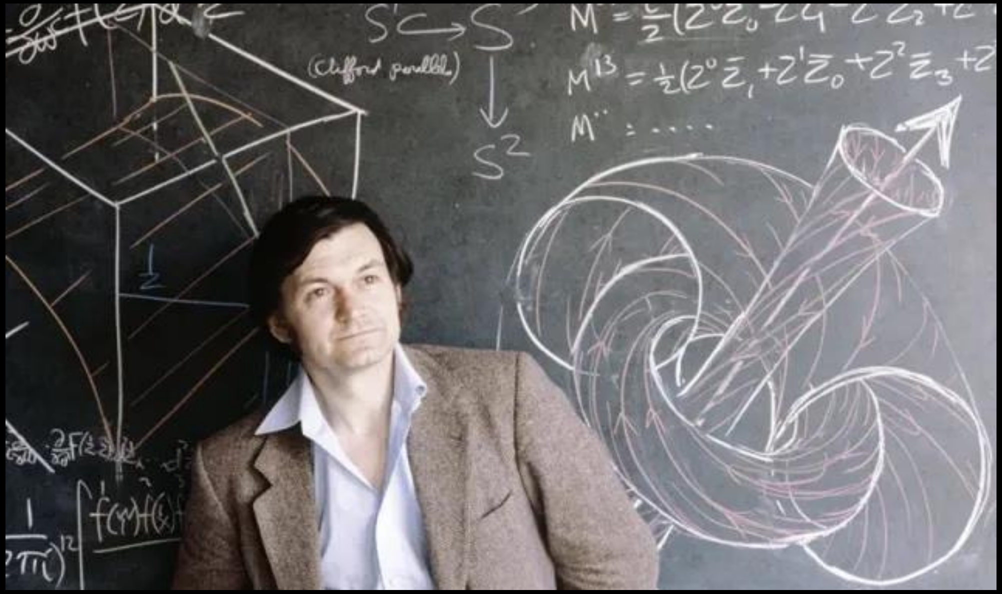
In 1970, Hawking & Penrose publish their ‘singularity theorems’, showing mathematically that the Universe must have begun as a space-time singularity.


Arno Penzias & Robert Wilson


Stephen Hawking & Roger Penrose



The Horn Antenna at Bell Labs in New Jersey.


Roger Penrose in the 1970’s.

Dark Energy

Earlier we discussed Einstein's 'biggest blunder', his Cosmological Constant.

Einstein added this term in to his equations as a mathematical fudge, so prevent the Universe from expanding.

Physically, this term can only arise from a constant (non-diluting) energy density.

Einstein's Cosmological constant

$$H^2 = \frac{8\pi G}{3}\rho - \frac{kc^2}{a^2} + \frac{\Lambda c^2}{3}$$

$\Lambda > 0 \longrightarrow$ Needed for a static Universe

$\Lambda < 0 \longrightarrow$ Leads to an accelerating Expanding Universe

Dark Energy

The Accelerating Universe

In 1998, Astronomers looking at type 1a supernovae were able to establish that the Universe is indeed accelerating its expansion.

The supernovae occur when a White Dwarf leachers material from a companion star sharing its orbit, leading to a runaway flash of nuclear fusion.

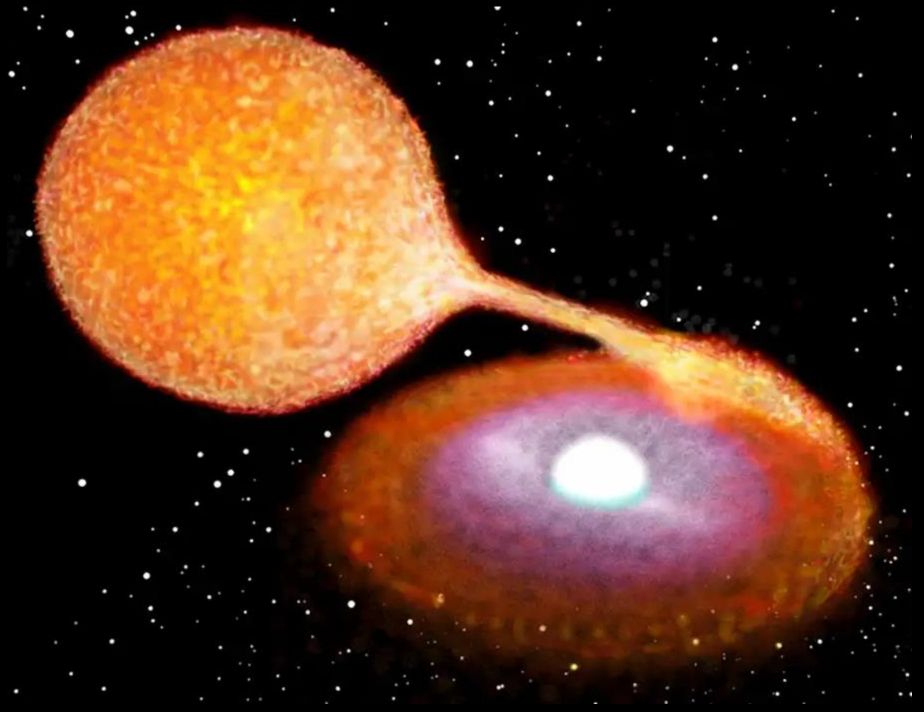


Illustration of a binary Red Giant-White Dwarf system.

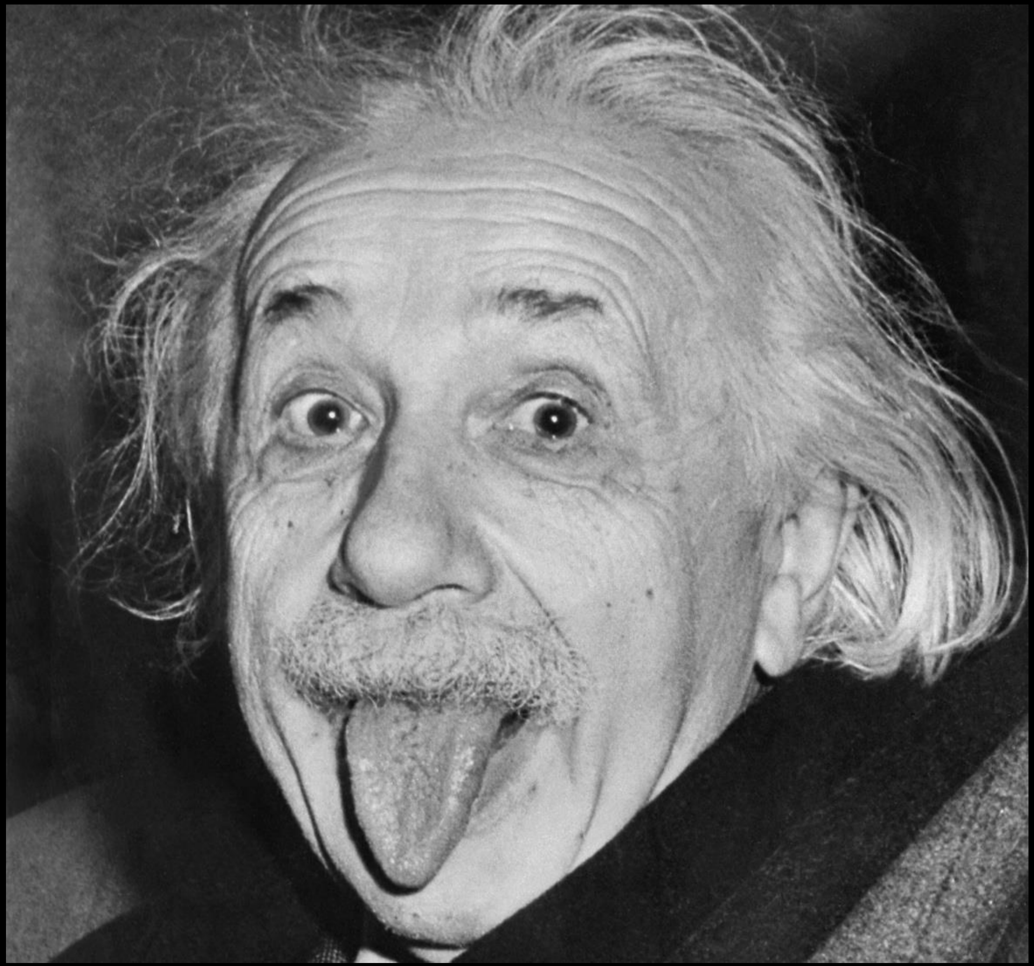
Tycho’s Nova, the remnant of a type 1a supernova.

Dark Energy

Einstein was right in the end! (Well.. Sort of…).

He introduced a positive cosmological constant to try and halt the expansion of the Universe, but we see some evidence for a negative cosmological constant, leading to an accelerating Universe.

Understanding where the cosmological constant originates, and how to calculate its value at a theoretical level is an open problem in physics (the cosmological constant problem).

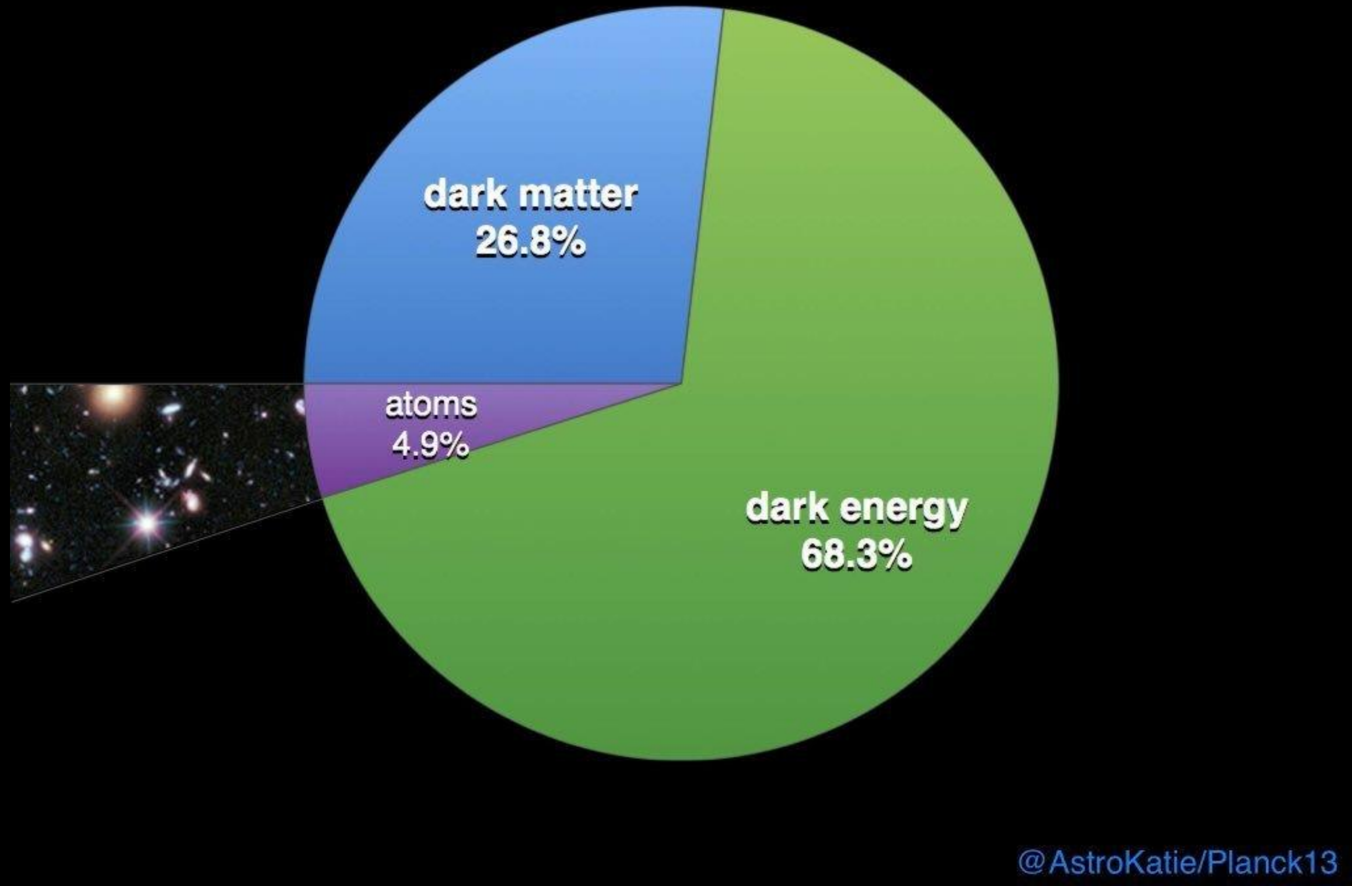


Dark Energy

Physically, we still don’t have a good description of what Dark Energy actually is…

This mysterious force dominates the evolution of our Universe on the largest scales, and makes up nearly 70% of all of the matter/energy in the cosmos.

This remains one of the biggest mysteries in modern physics.



Part V – The Multiverse

‘The Multiverse’

There are different kinds of **hypothetical** multiverses described by theoretical physicists, including:

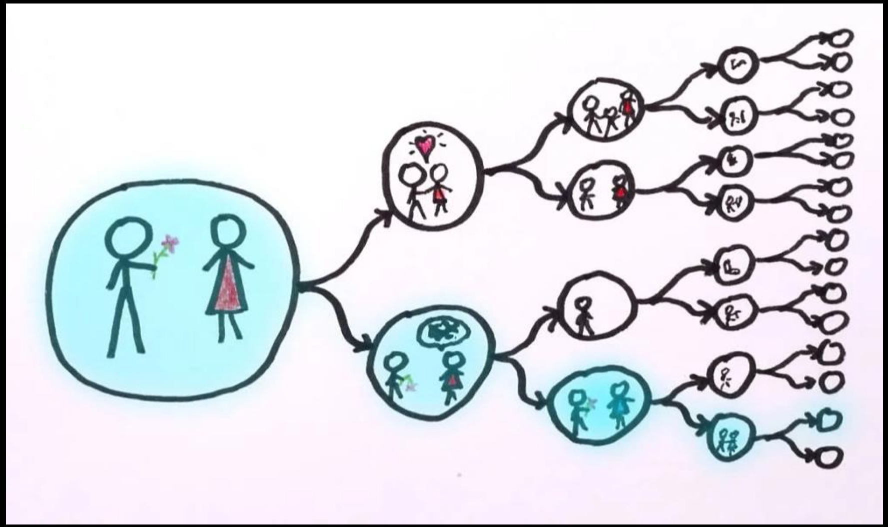
Level 1: ‘Eternal Inflation Multiverse’.

A consequence of the hypothetical rapid expansion of the Universe (inflation), which leads to pockets of space causally disconnected from out own Universe. This type of Multiverse is basically just ‘more Universe’.

Level 3: The ‘Everett Multiverse’.

Named for Hugh Everett’s ‘Many Worlds Interpretation’ of quantum mechanics.

Illustration of ‘the Multiverse’.



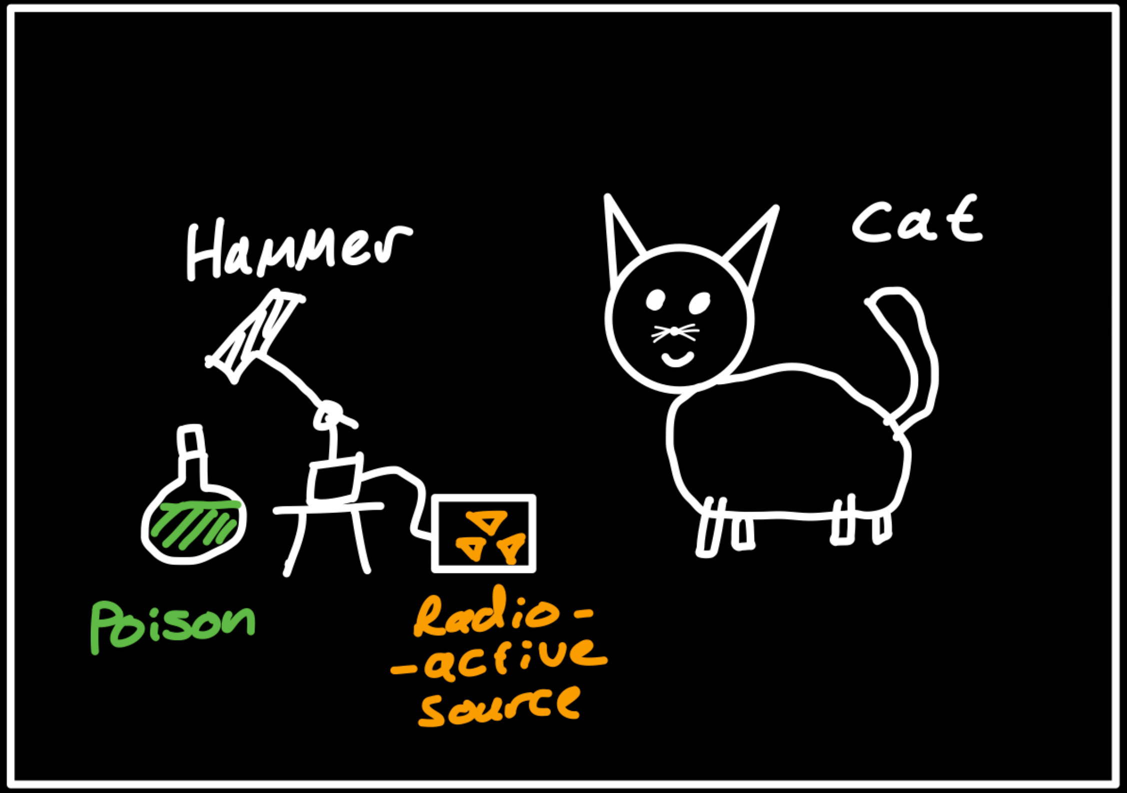
Fissioning in an Everett Multiverse.

Schrödinger's Cat

Schrödinger's Cat is an analogy for describing the indeterminate nature of a Quantum State, prior to observation.

In this thought experiment: A cat is placed into a box, with a vial of poison, and a hammer system poised to smash the vial if a radioactive atom decays (a totally random process).

We can use this to outline both the Many Worlds, and Copenhagen interpretations.



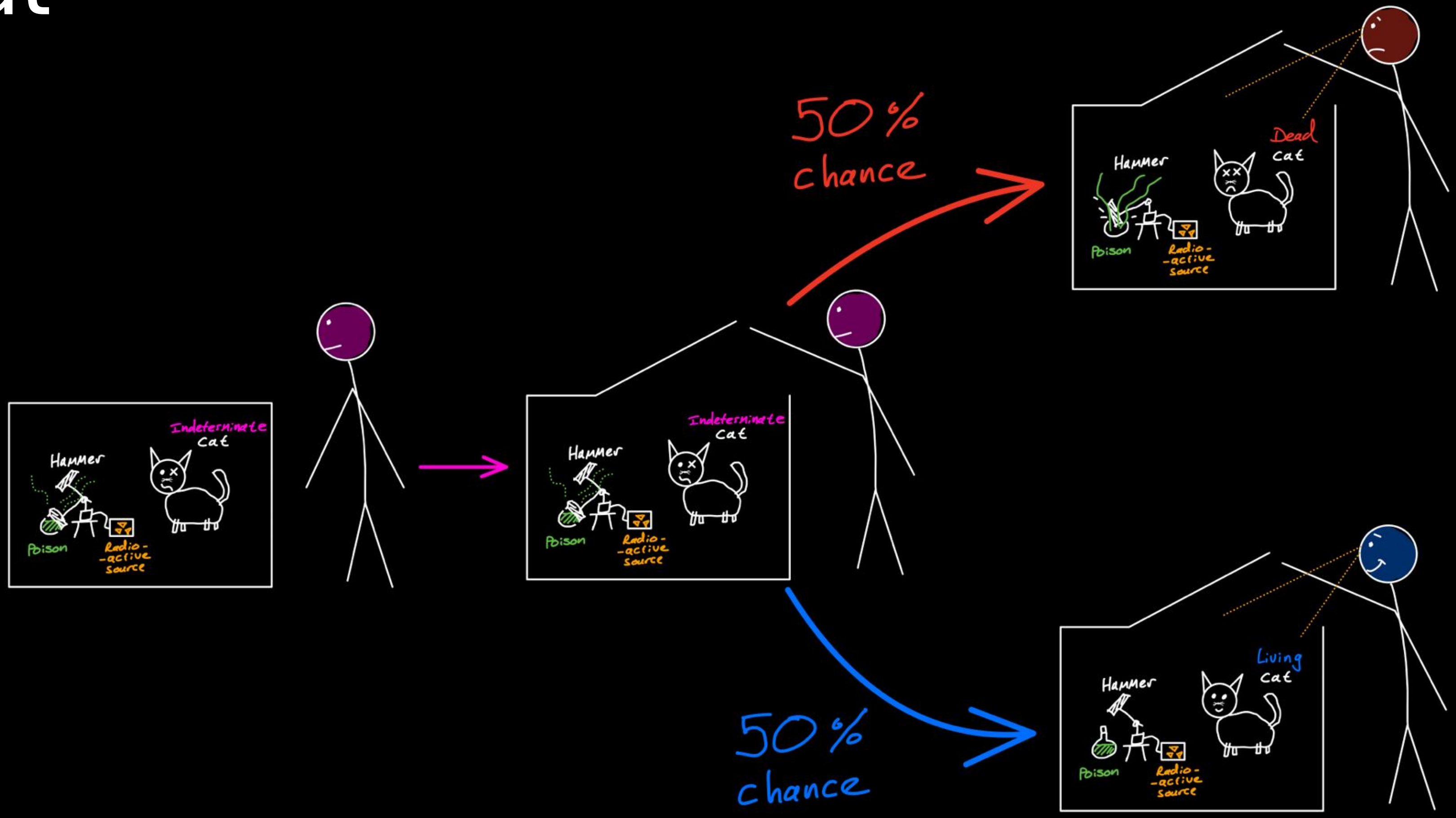
Schrödinger's Cat

The Copenhagen Interpretation

The cat exists in an indeterminate state (a Quantum Superposition), in which it is both dead and alive simultaneously.

It does not become one of the other until we open the box, and collapse the wave-function of it's quantum state.

Note: It *really is* indeterminate!... This is not the same as us simply not knowing... **The Universe itself does not know, until the box is opened!**



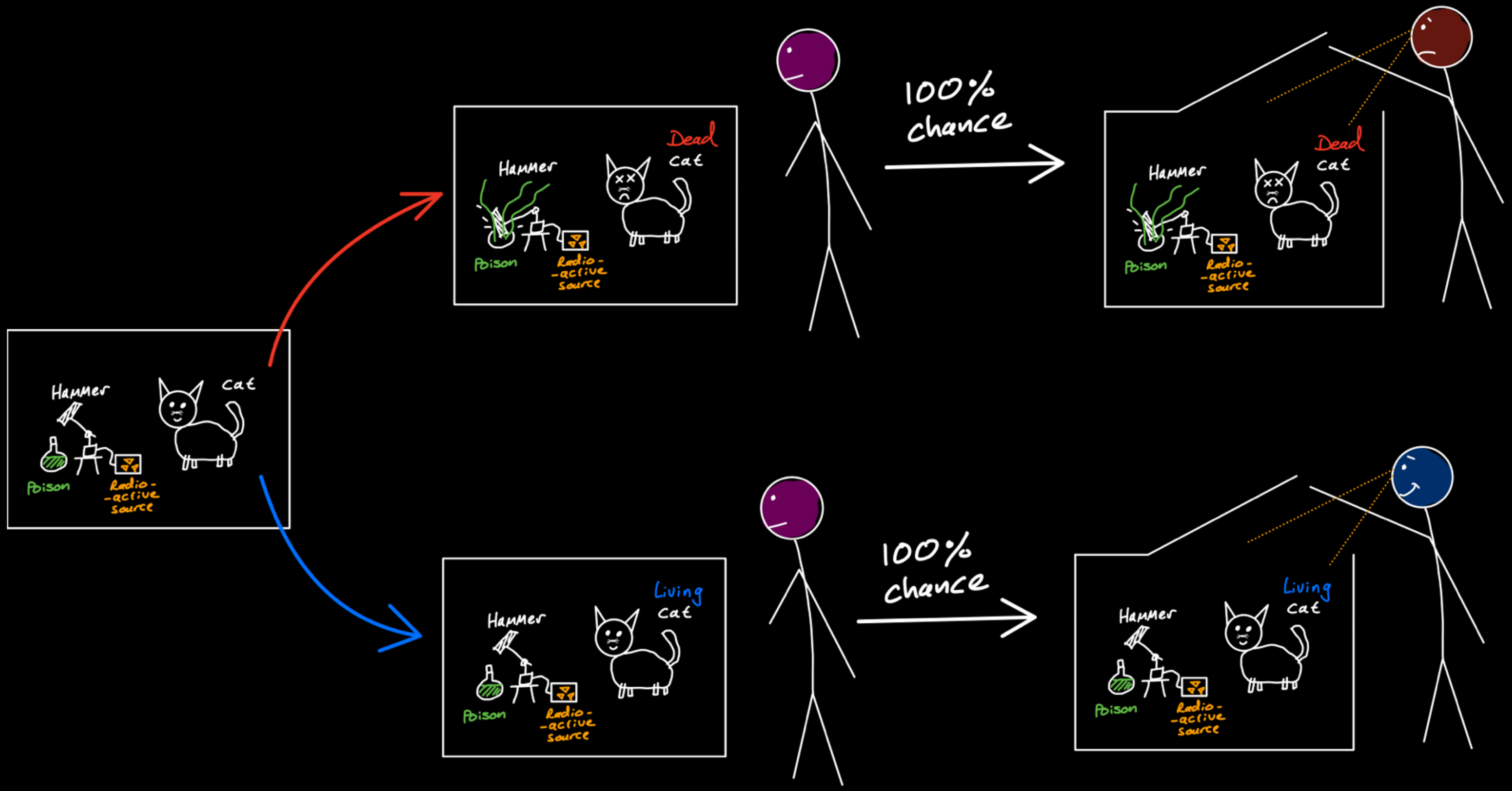
Schrödinger's Cat

The Many Worlds Interpretation

When the cat is placed into the box, two outcomes are possible:

1. The vial smashes and the cat dies.
2. The vial does not smash, and the cat lives.

In response to this binary choice, the Universe splits in two. One Universe where the cat lives, and one where the cat dies. We exist in one of these Universes, but we have no way of knowing which until we open the box.



Questions!

Spacetime Sundays

Southend's First Science Community Drop-in:

part office-hour, part lecture, part book club

Approximately every other Sunday 11am-12pm in the Beecroft Gallery Foyer

Upcoming dates:

19/07 [**tomorrow!**]

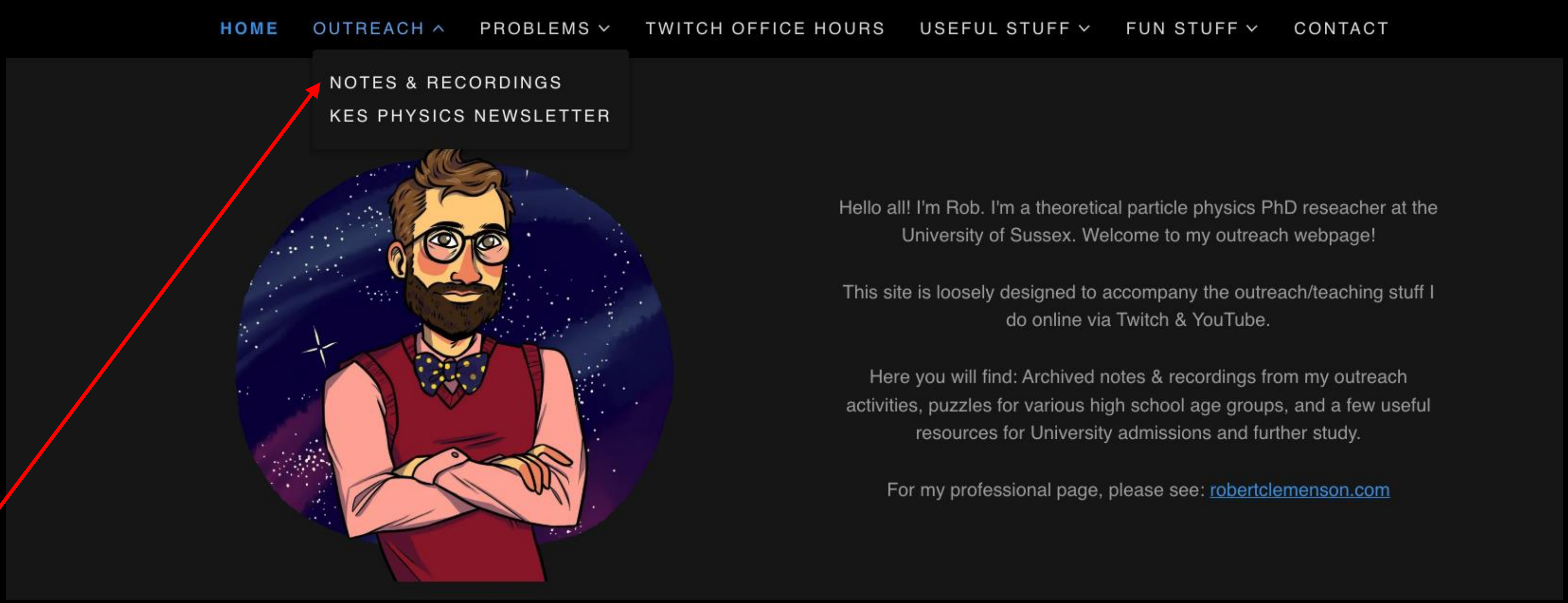
02/08

16/08

Join the Mailing List for Updates!

Visit: Spacetime-Sundays.com

Lecture Slides



These lecture slides are available on my outreach website:

CosmicConundra.com

Coming Up…

Watch this space, and subscribe to the Spacetime Sunday Mailing List

~~*Building a Universe from Scratch (06/06)*~~

~~*Black Holes: Monsters of the Cosmos (20/06)*~~

~~*The Physics of Science Fiction: Tardises, Teleports, and beyond… (04/07)*~~

~~*“Not Even Wrong”: The Strangest Ideas in Theoretical Physics (18/07)*~~