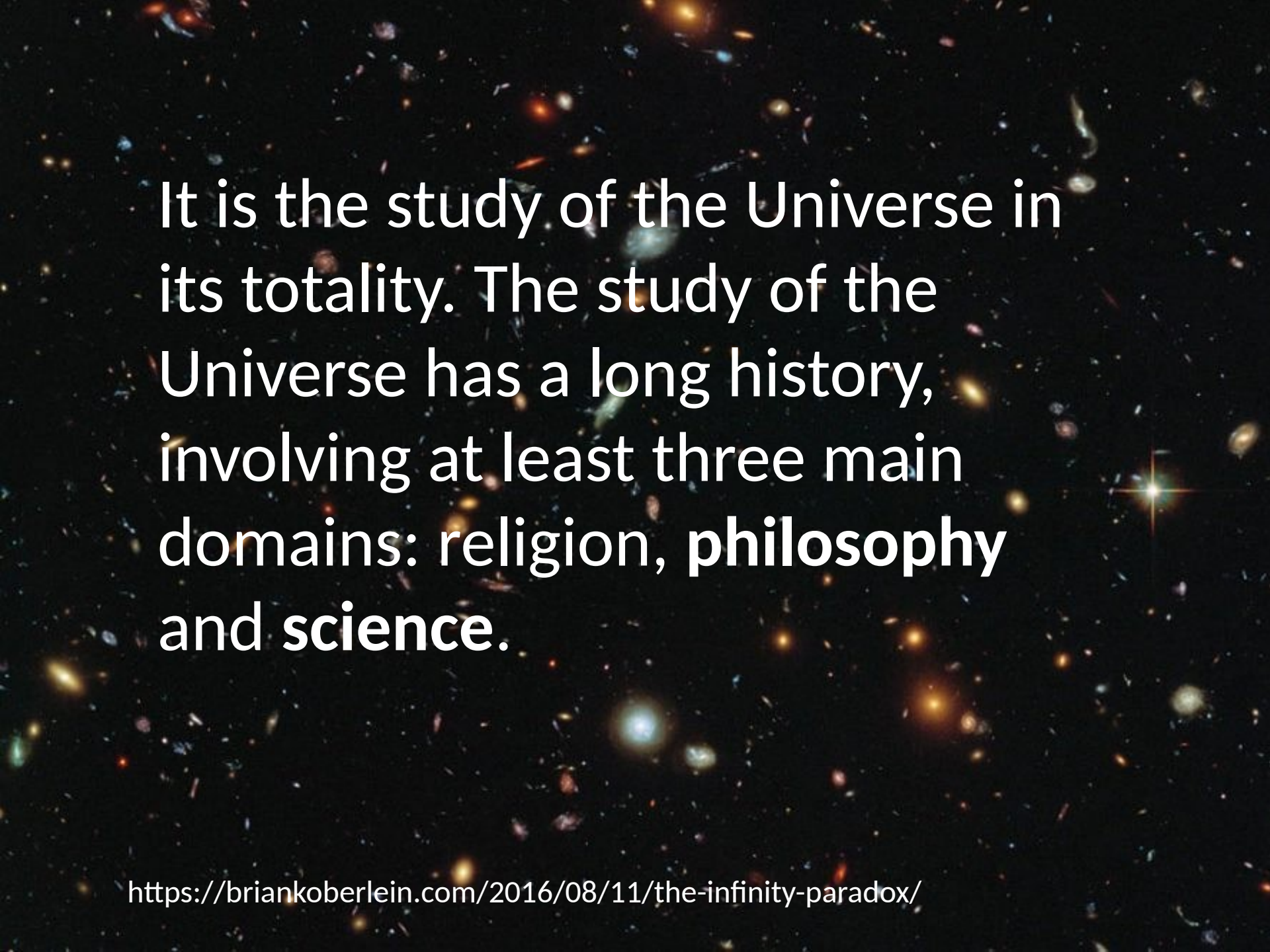


cosmology

noun [koz-mol-uh-jee]

Natural

the branch of philosophy dealing with the origin and general structure of the universe.



It is the study of the Universe in its totality. The study of the Universe has a long history, involving at least three main domains: religion, **philosophy** and **science**.

Fine tuning and the Anthropic Principle

Fine tuning

- “Our universe looks very unusual, highly non-generic, and in the past it was even more non-generic, or ‘finely tuned’.” *Sean Carroll*
- Which are the critical parameters?
- What is the evidence for fine tuning?
- Is the Universe fine-tuned for us, or
are we fine tuned for it?
- Implications of the multiverse?

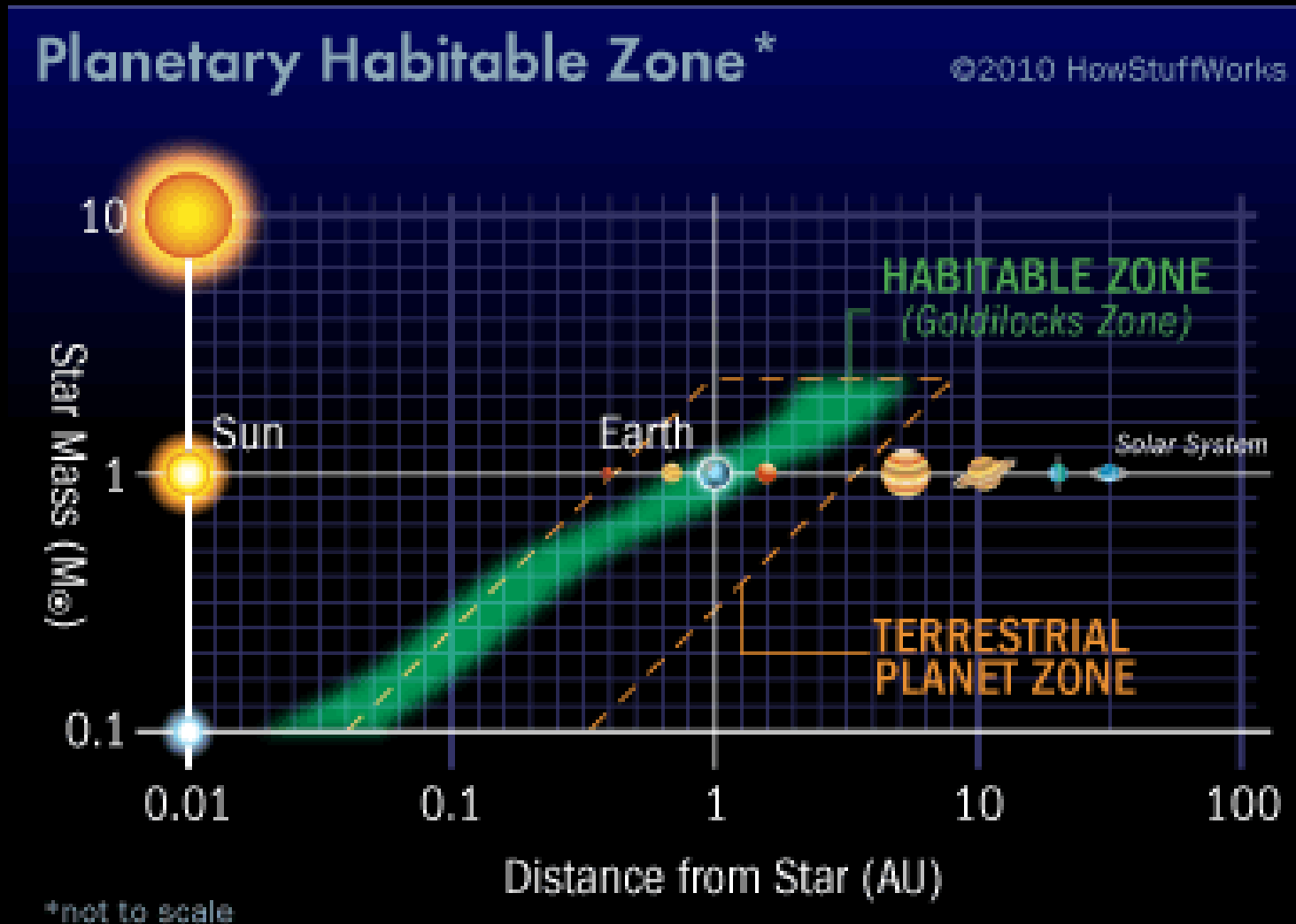


Main fine tuned parameters

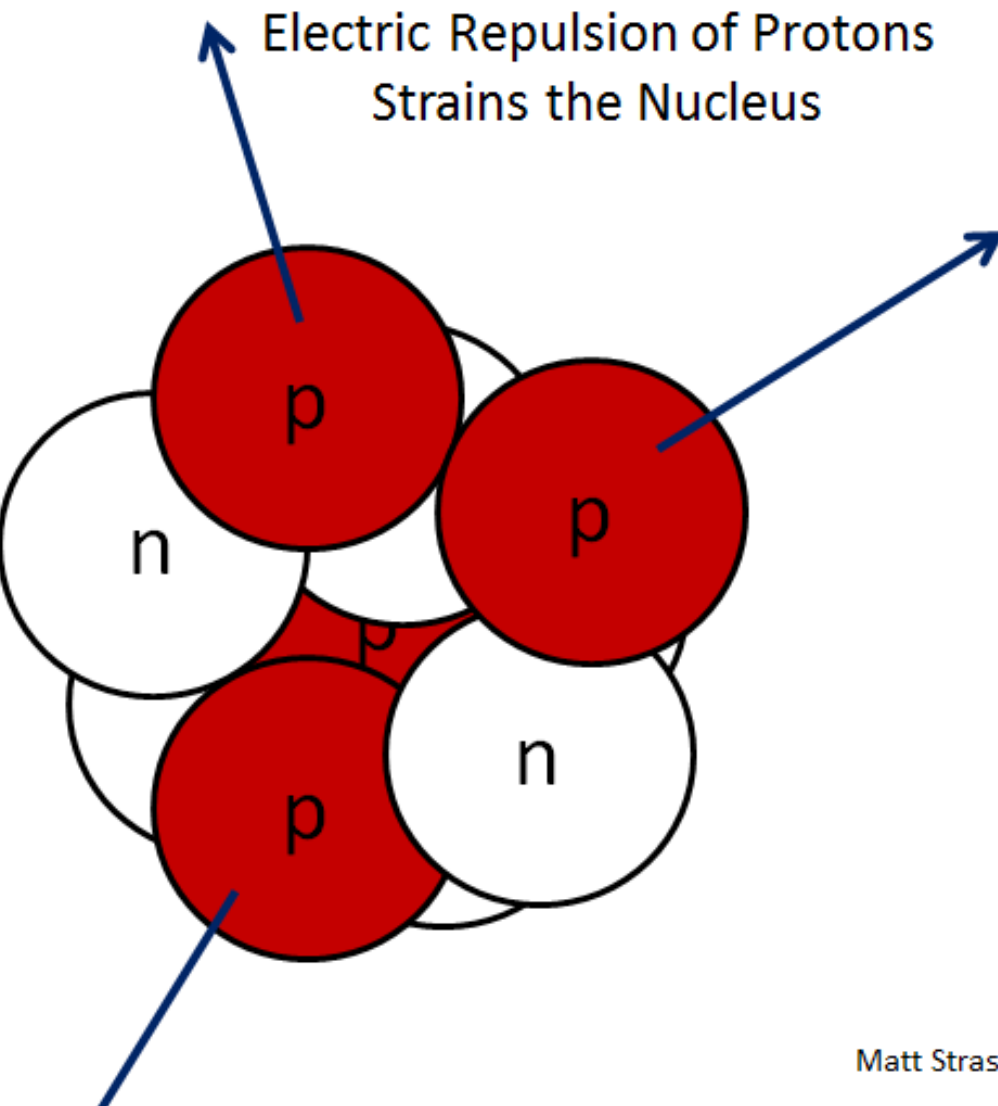
- **Cosmic constants** – four fundamental force constants and the cosmological constant
- **Initial conditions** – distribution of mass energy, velocity of light, ratio of masses for protons and neutrons, matter-antimatter asymmetry.
- **Local planetary conditions** – within galactic habitable zone, within circumstellar habitable zone, right planetary mass, presence of liquid water, plate tectonics steady, during cosmic habitable age, etc.

(Rees: “Just Six Numbers”)

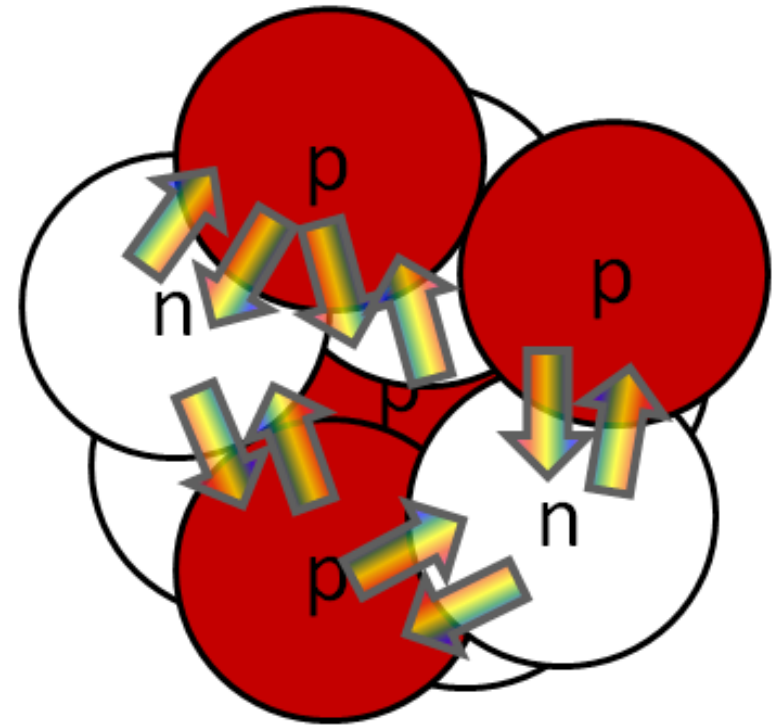
1. Where we are in the Solar system



2. Strength of nuclear strong force versus electromagnetic force, 137:1



But The (Residual) Strong Nuclear
Force Holds the Nucleus Together

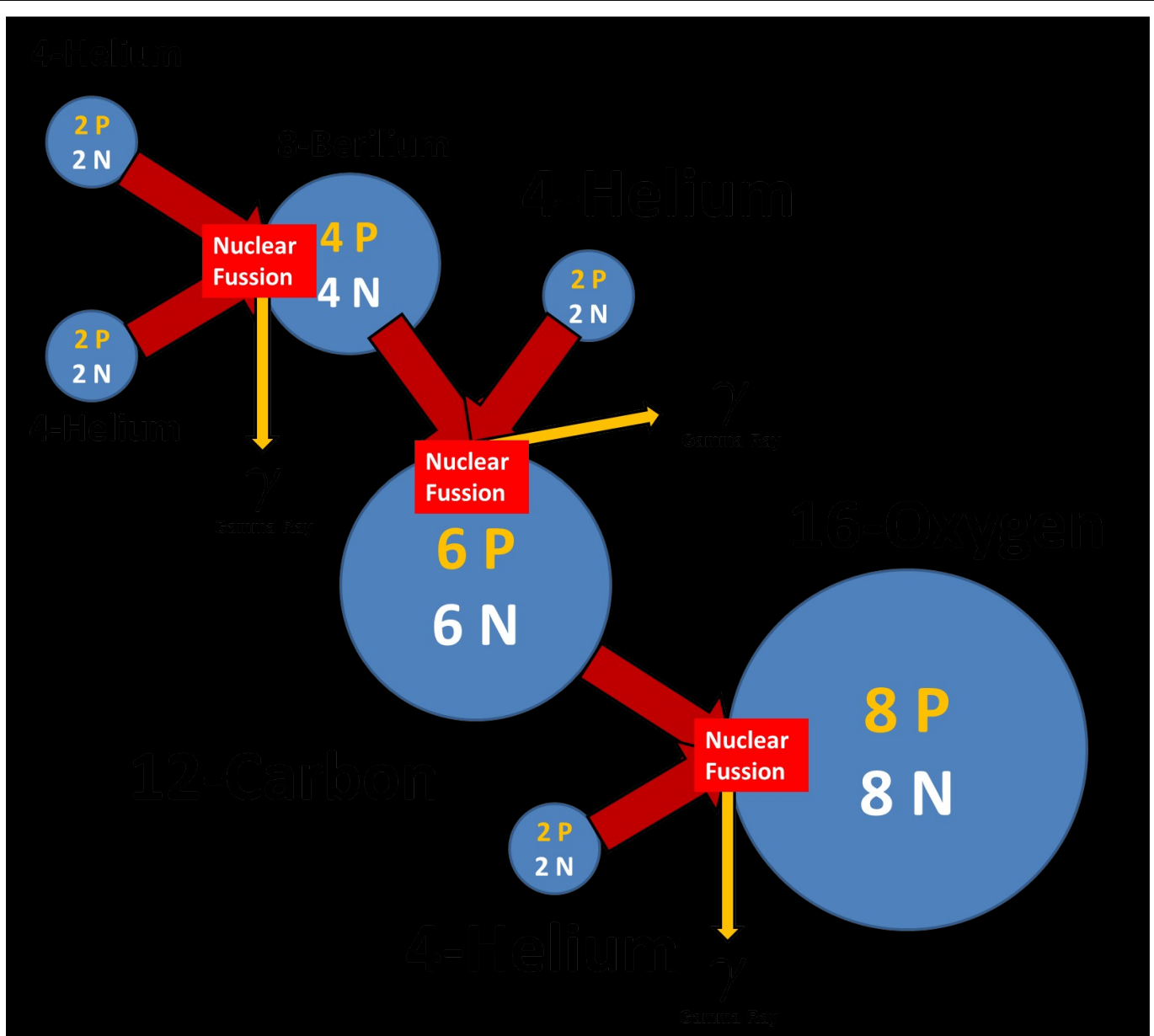


Strength of nuclear strong force vs electromagnetic force

- H in sun converts 0.007 of its mass into energy when it fuses to helium, efficiency $\epsilon=0.007$
- Determines how long stars can live
- If $\epsilon\sim 0.006$, nuclear forces weaker, can't get to He and elements beyond
 - simple universe, no enrichment
- If $\epsilon > 0.008$, nuclear force stronger, heavy nuclei form too easily, no H survives from Big Bang,
 - no fuel for stars, no water.
- Complex chemistry requires 0.006-0.008

(Rees: "Just Six Numbers")

Carbon



3. Carbon (Hoyle, 1952) and the triple alpha process


- C made from 3 He, via Be, Be unstable
- Hoyle, C nuclear ground state energy levels have to be in resonance – particular energy predicted – and found
- Resonance very sensitive to strong nuclear force
- Variation >a few % either way in ϵ from 0.007 – no carbon, no carbon based life

Fundamental forces

Force	Strength
Strong Nuclear	1
Electromagnetic	$1/137=0.007$
Weak Nuclear	10^{-6}
Gravity	10^{-39}

4. N – strength of electrical force vs gravitational force

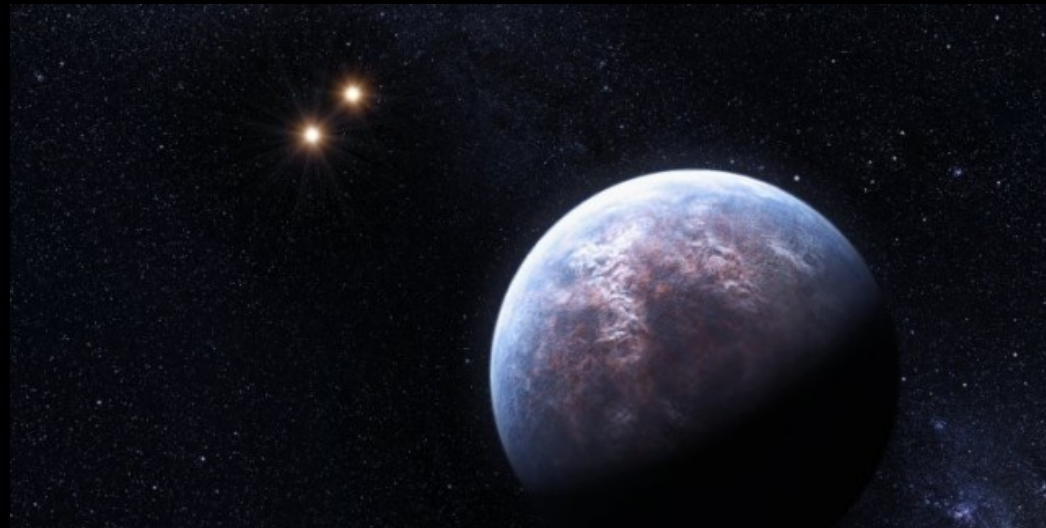
- $N = (\text{electromagnetic force between two protons}) / (\text{force of gravity between them})$
 $N \sim 10^{36}$ – gravity is **VERY** weak
- Gravity is **ONLY** attractive
- Gravity organises the cosmos and is critical for structure formation
- If N decreased, ie. if gravity were stronger
 - Short lived miniature universe, closely packed together, unstable
 - No time for complex biological evolution
 - No creatures larger than insects
- If gravity weaker, planets and stars can not form at all



No doubt about it,
the universe IS very
finely tuned!

How finely tuned is the Universe for Life?

- But is it really fine tuned for life?
- Most of universe probably very hostile to life as we know it.
- 10^{11} stars in our galaxy alone
- Finding thousands of planets round other stars



The Anthropic Principle

- The **anthropic principle** is a philosophical consideration that observations of the Universe must be compatible with the conscious and sapient life that observes it.

(https://en.wikipedia.org/wiki/Anthropic_principle)

Various Anthropic principles

- **Strong Anthropic Principle (SAP):** Universe **must** have properties which make it **inevitable** that conscious life will develop (Barrow and Tipler).
- **Weak Anthropic Principle (WAP)**– only get sentient beings in universe which can support them

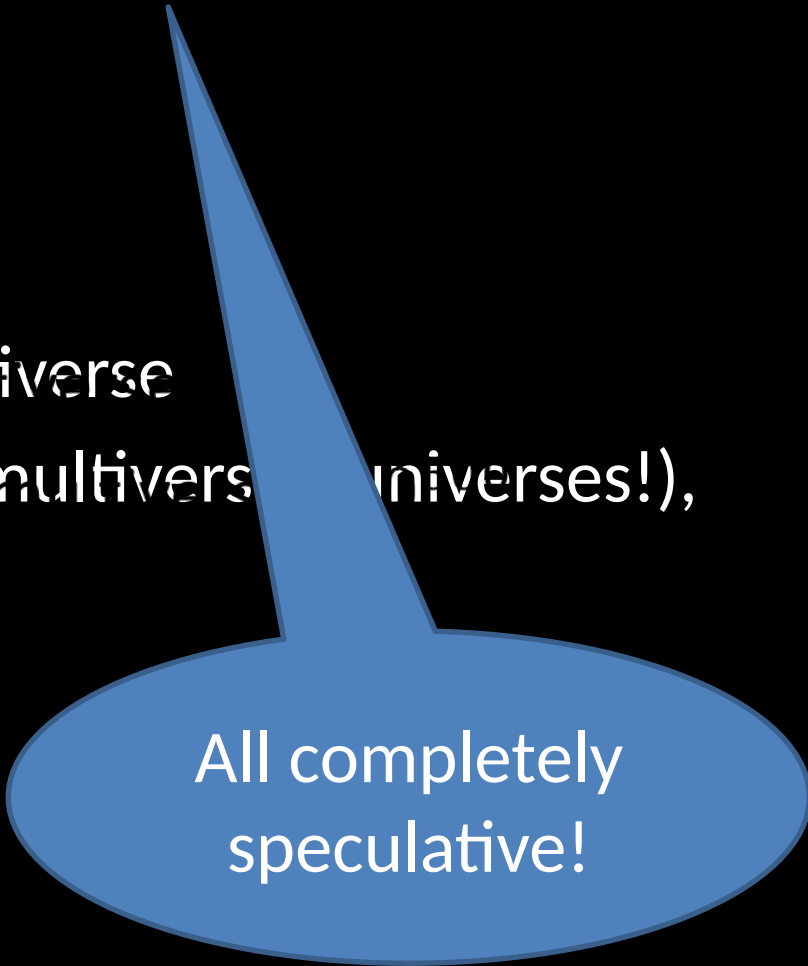
What does this mean?

- Interpretations:
 - one possible Universe 'designed' for 'observers'.
 - observers needed to bring Universe into being
 - ensemble of other universes needed for existence of our Universe.

Beyond the Big Bang

- **Only by mathematics, no observational proof possible**
 - Theory of everything
 - Quantum “Many Worlds”
 - Eternal inflation - The Multiverse
 - String Theory, M-Theory – multiverses (universes!), and ~11 dimensions

Now being questioned as unprovable – metaphysics!



All completely speculative!

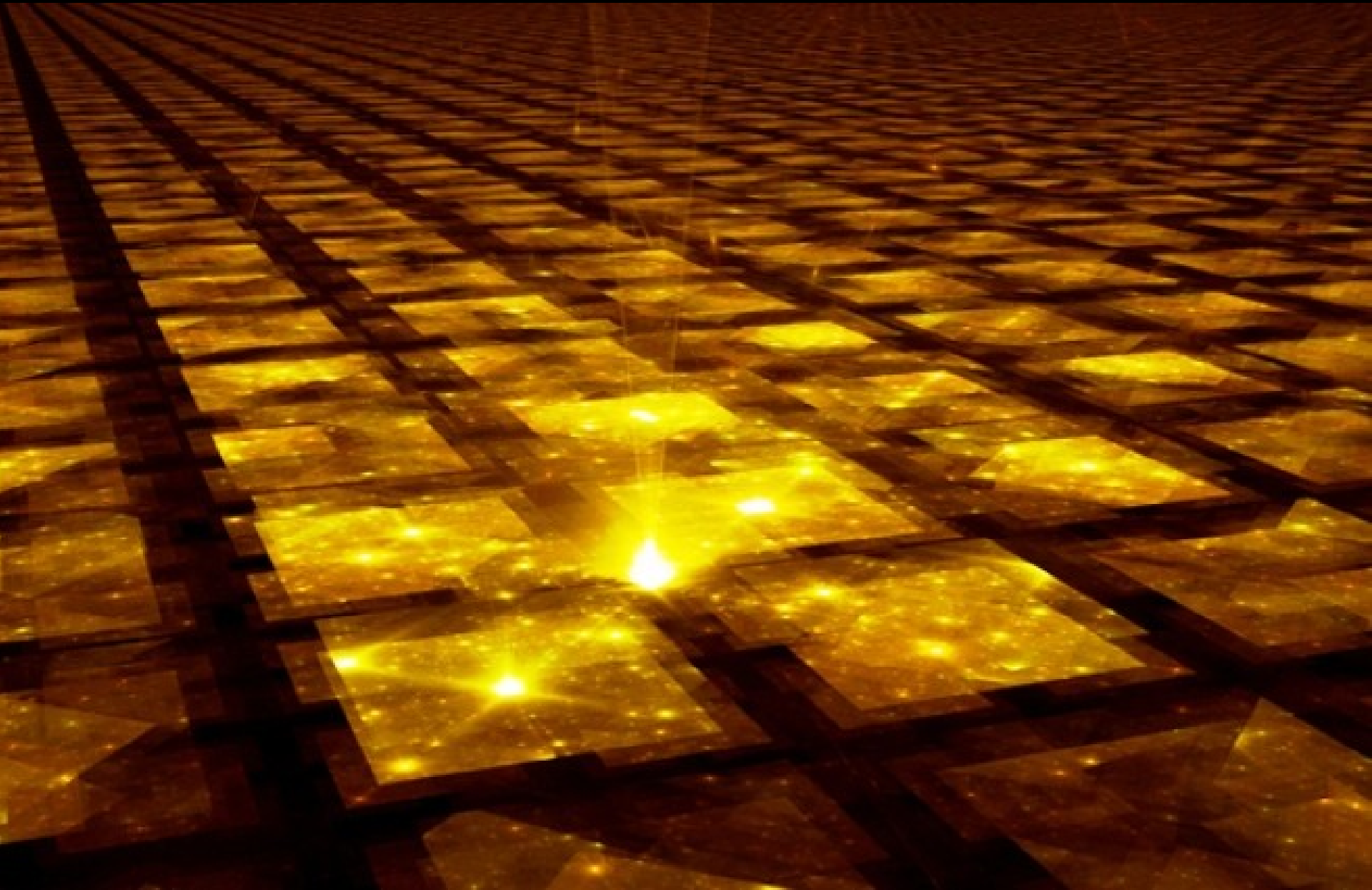
A Theory of Everything (TOE)

- One Theory explains all - complete unification at the heart of nature
- This Universe is the only universe
- Has to explain why all the constants are the way they are
- Has to explain why it is bio-friendly
- Not yet achieved

Are we living in someone else's simulated universe?



Infinitely repeating Universe



Eternal inflation

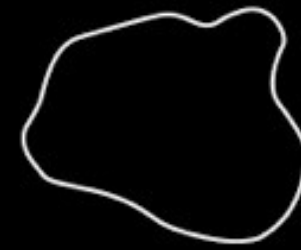
This theory says that new universes pop into existence at an unknown rate, creating a complex web of bubble universes within a vast multiverse.

Astronomy: Roen Kelly



Never –
ending
repro-
duction
of
inflated
regions.
Multi-
verse

String Theory Concepts



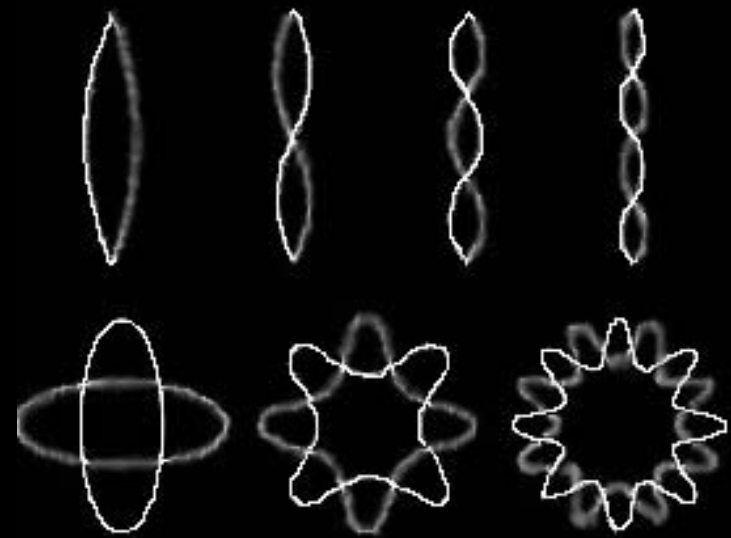
Closed string

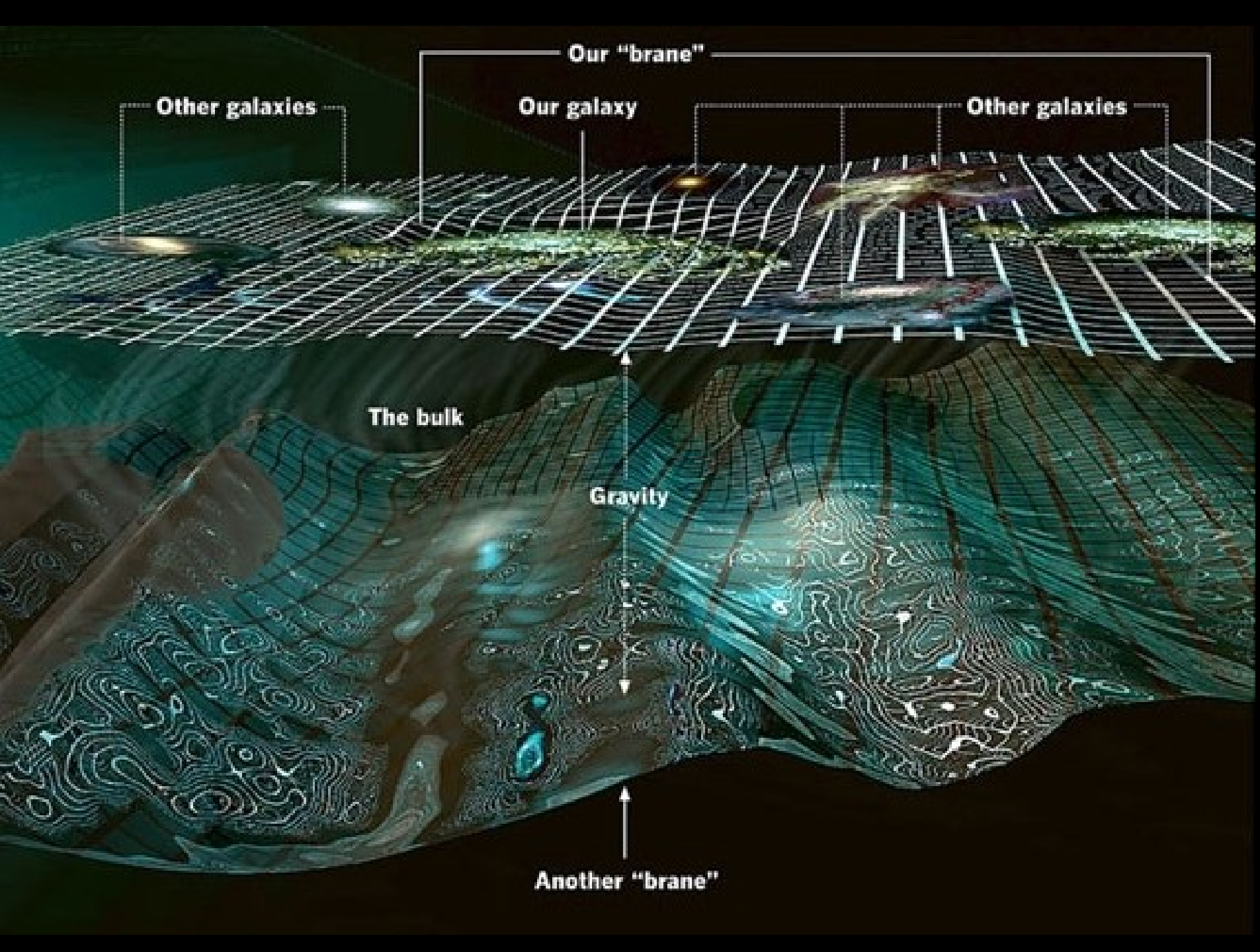


Open string

- Particles are vibrations of very tiny 1-d strings (10^{-33} cm – Planck scale, under very high tension)
- Every force transmitter is a vibration in a field
- “Stuff” of matter and forces is the same
- Differences arise because different resonant frequencies – universe like cosmic symphony

String Theory







simulated Universes

Maths - the true reality *

Quantum Many Worlds

TOEs

Quantum
Cosmology

Eternal Inflation

String Theory

The Multiverse

**Plausibility,
Falsifiability?**

Where is cosmology going now?

- All these cosmologies non-verifiable!
- Doubts because predicted fundamental particles not being seen by LHC
- Physics standard models are NOT secure
- Ready for new paradigm? Yes!
- Also need to understand dark matter and dark energy
- And to measure primordial gravitational waves



Not the End, it's just
the Beginning!