

String theory and the shape of nature

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Plan

1. What we understand
2. What we don't understand
3. String theory

What we understand

Really quite a lot

What we understand

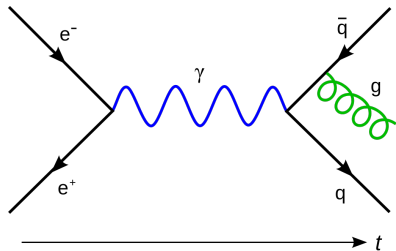
Quantum mechanics

- ▶ Describes matter and forces
- ▶ Particles are point-like and move on spacetime
- ▶ Nature is probabilistic and uncertain

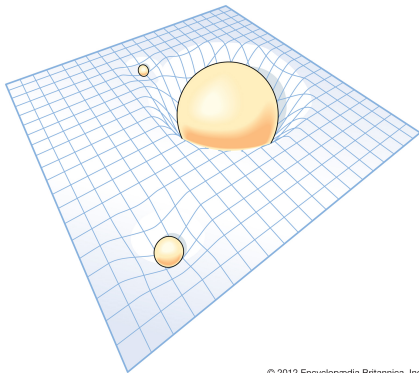
General Relativity

- ▶ Describes gravity
- ▶ Matter bends and warps spacetime
- ▶ Spacetime tells matter how to move
- ▶ Nature is smooth

What we understand



vs



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What we don't understand

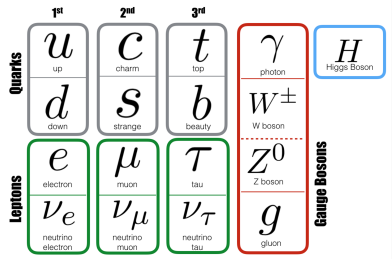
Quantum gravity

- ▶ Gravity is strong and QM important
- ▶ Black holes? Big Bang?

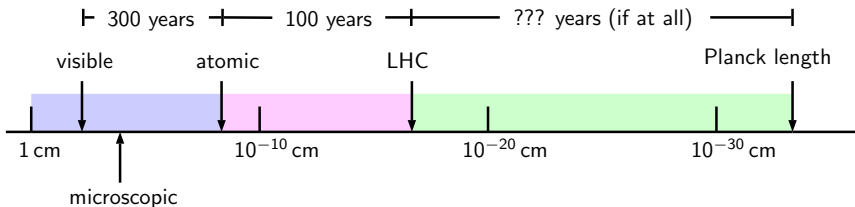


Why these laws of physics?

- ▶ Why only one electron?
- ▶ Why do we have the forces we have?
- ▶ Standard Model?



Why is this difficult?

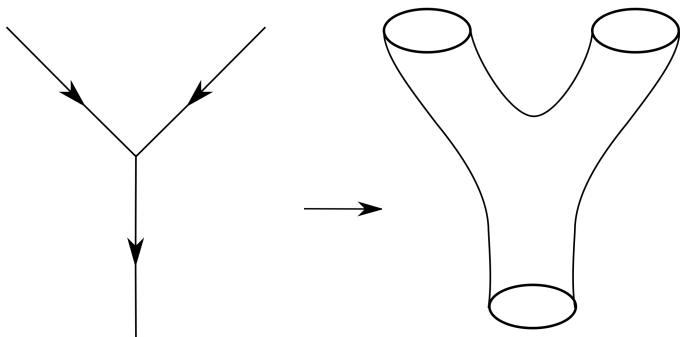


“Quantum gravity” important at Planck length $\sim 10^{-33}$ cm

No experimental guidance

Use known laws and consistency instead

What is string theory?

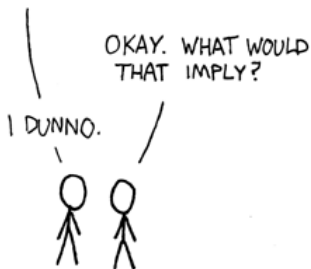


Idea: replace point particles by strings

What is string theory?

STRING THEORY SUMMARIZED:

I JUST HAD AN AWESOME IDEA.
SUPPOSE ALL MATTER AND ENERGY
IS MADE OF TINY, VIBRATING "STRINGS."



What is string theory?

Strings are *very* small $\sim 10^{-33}$ cm

- ▶ “Notes” of the string give different particles

Combines quantum mechanics and gravity

Strings are greedy – they live in 10 dimensions

- ▶ Other 6 are small and curled up

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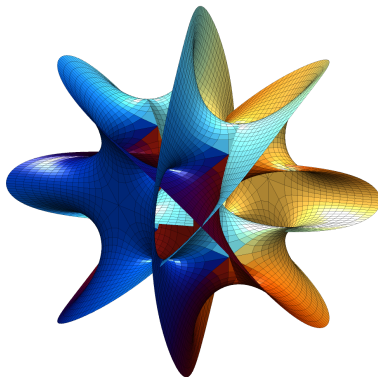
- ▶ Other 6 are small and curled up

What shape can the curled up directions take?

Physical laws from geometry

“Internal” space affects how the string can vibrate

- ▶ Different shapes for the internal space give different particles in our 4d universe
- ▶ Physics in 4d \leftrightarrow allowed shapes or geometries



What kind of universes can string theory describe?

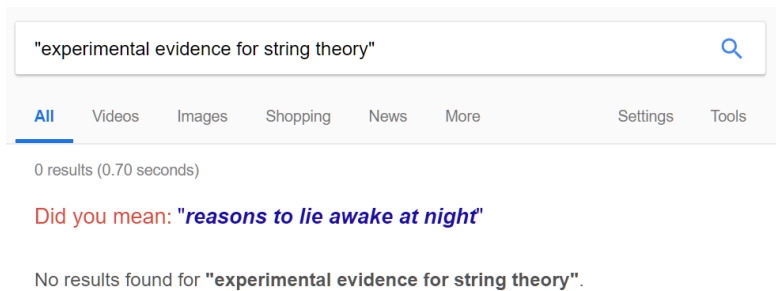
Different laws of physics come from different geometries

- ▶ Study geometry to map out possible universes
- ▶ Large but finite “menu” – 10^{500} ? $10^{20,000}$?

We can study general properties instead of case-by-case

- ▶ Develop mathematical language suited to string theory

Where do we go from here?



We don't have direct experimental evidence

Summary

String theory is:

- ▶ The only known theory that reconciles quantum mechanics and gravity
- ▶ A way to understand physics via geometry

String theory is not:

- ▶ Finished
- ▶ Directly testable in the near future

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Quantum gravity is hard!

Thank you