Strings for Dummies

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Why String Theory?

What we know:

- The universe is governed by 4 fundamental forces:
  - Electromagnetism
  - Weak interaction
  - Strong interaction
  - Gravity
- At microscopic scales nature is described by a quantum theory (QFT)
- We have a very good classical description of gravity (GR)
- Symmetry is a guiding principle (Gauge Theories)
- We have been successful in unifying electromagnetism and weak interaction [Glashow,Weinberg,Salam'79]
- Electroweak + QCD = Standard Model

Why String Theory?

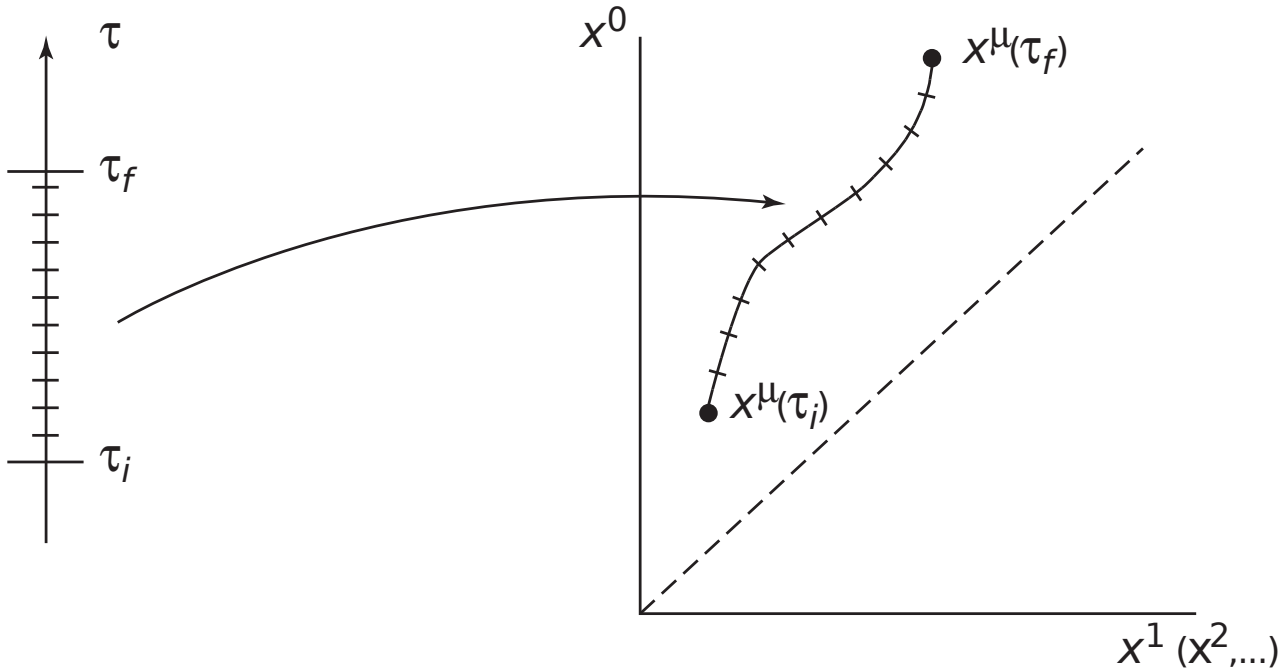
Difficulties arise when one attempts to apply the usual prescriptions of quantum field theory to gravity (renormalization problem)

Theories of quantum gravity seek to describe the force of gravity according to the principles of quantum mechanics. The most promising of all such theories today is **string theory**.

String theory is a **single mathematical framework** which includes all fundamental forces!

What are strings?

Classical and quantum mechanics are based on the concept of point particle.

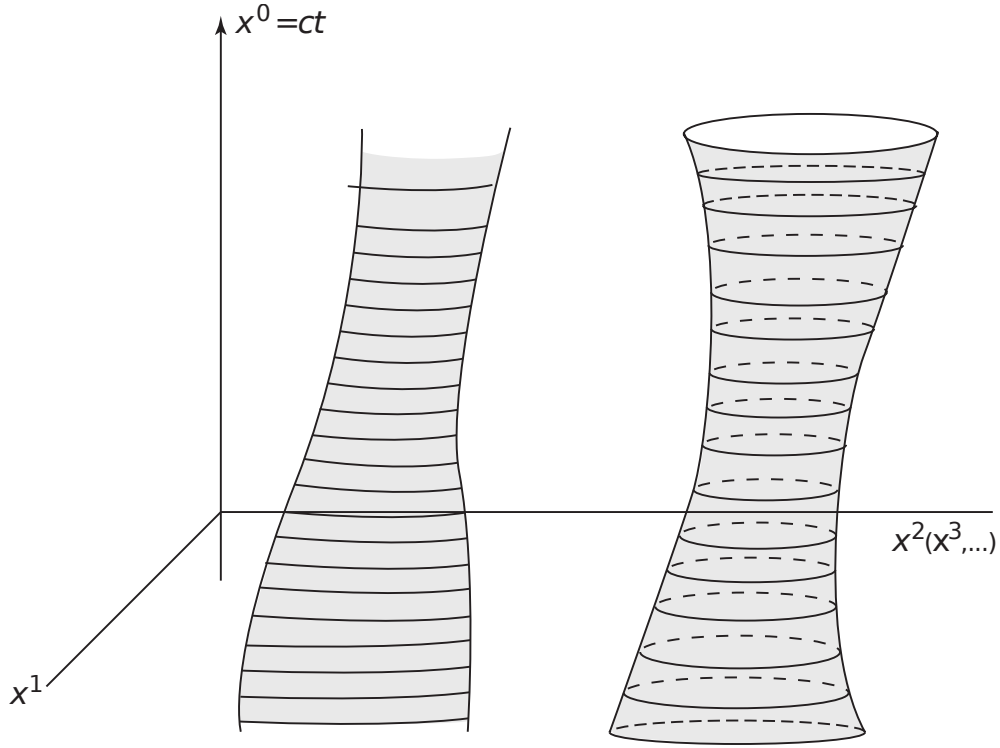


The trajectory of the particle is called the **worldline**.

$$S = Length(worldline)$$

What are strings?

Instead of point-like object let us consider 1-dimensional extended objects (strings).



The trajectory of the string is called the **worldsheet**.

$$S = Area(worldsheet)$$

What does it predict?

- Particles emerge as quantum excitations of the string
- Open strings give rise to gauge fields (*photon*, *gluon*)
- Closed strings give rise to massless spin-2 particles (*graviton*)
- Number of spacetime dimensions (D=10)
- Microscopic origin of the black hole entropy

$$S = \frac{Area(Horizon)}{4G\hbar}$$

- A lot more...

Criticisms

- Where are the 6 extra dimensions?
  They are "compact".
- How can we experimentally test the theory?
  Stay tuned.
- Does quantum gravity need string theory?
  It is the best candidate so far.

Gauge/Gravity duality

It is a conjectured relationship between two kinds of physical theories. On one side are theories of quantum gravity, formulated in terms of string theory. On the other side are conformal field theories which are gauge theories that describe elementary particles. [Maldacena'97]

Hard problems in one side of the duality are translated into simple problems in the other.

"I just think too many nice things have happened in string theory for it to be all wrong. Humans do not understand it very well, but I just do not believe there is a big cosmic conspiracy that created this incredible thing that has nothing to do with the real world."

— *Edward Witten*