

The What and Why of Superstrings

U. A. Yajnik

- Quick overview
- Universality
- Unification
- Fundamental particles - pieces of the puzzle
- String physics : All of the above

[Home Page](#)

[Title Page](#)

[Contents](#)

[◀](#) [▶](#)

[◀](#) [▶](#)

Page 1 of 14

[Go Back](#)

[Full Screen](#)

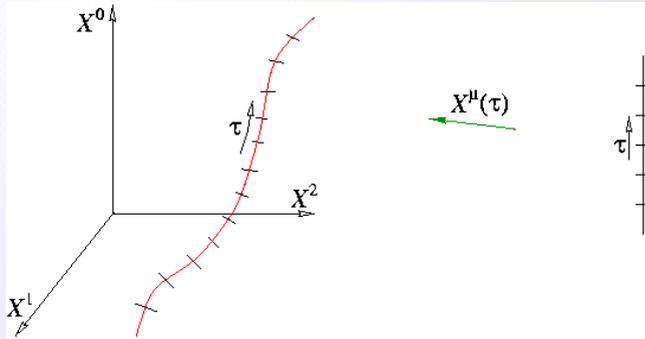
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[Quit](#)

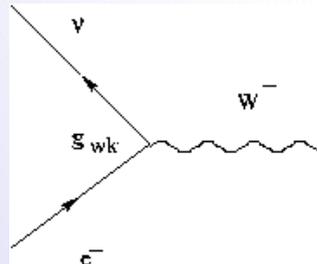
Quick overview

The particle picture

Feynman spacetime picture



Building blocks of scattering



Coupling strength “g” different for each fundamental force

Home Page

Title Page

Contents

◀ ▶

◀ ▶

Page 2 of 14

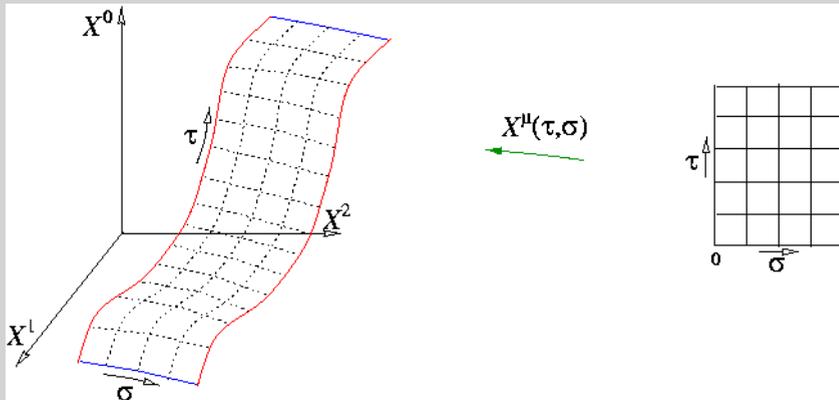
Go Back

Full Screen

Close

Quit

The String picture



Dynamics determined by the **geometric** principle :

$$\int d(\text{Area traced}) = \text{extremum}$$

Suffices to determine

- Fundamental particles and their charges
- All the interactions among them

End of quick overview

Home Page

Title Page

Contents

◀ ▶

◀ ▶

Page 3 of 14

Go Back

Full Screen

Close

Quit

Universality

Empirical laws

- Spring constants, elastic and viscous moduli

Universal laws

- Newton's law of Gravitation $\rightarrow G_N$
- Coulomb's law $\rightarrow \frac{1}{4\pi\epsilon_0}$

Universality = One coupling constant for divers situations

Home Page

Title Page

Contents

◀ ▶

◀ ▶

Page 4 of 14

Go Back

Full Screen

Close

Quit

Unification of forces

Newton's universal Gravity \longrightarrow unification across distance scales

- Unified fall of the apple with motion of “heavenly” bodies.
- Determined terrestrial g in terms of G_N .

Maxwell's equations \longrightarrow unification of Electricity and Magnetism

- $c^2 = \mu_0 \epsilon_0$ a universal constant independent of E-M.
- Understanding of light as electromagnetic waves

[Home Page](#)

[Title Page](#)

[Contents](#)

[◀](#) [▶](#)

[◀](#) [▶](#)

Page 5 of 14

[Go Back](#)

[Full Screen](#)

[Close](#)

[Quit](#)

Universality and symmetry principles

Newton's/Coulomb's law \longrightarrow Conservation of flux

Force $\propto (1/r^2)$, Surface area of sphere $\propto r^2$

Maxwell's equations \longrightarrow dynamical conservation of flux

Conserved flux \leftrightarrow conserved charges as sources

[Home Page](#)

[Title Page](#)

[Contents](#)

[◀](#) [▶](#)

[◀](#) [▶](#)

Page 6 of 14

[Go Back](#)

[Full Screen](#)

[Close](#)

[Quit](#)

Charge quantization

... *i.e.*, Fundamental particles

Charge values

strong, weak, weak hypercharge and EM

	g_{st}	g_{wk}	g_Y	$g_{EM} = g_{wk} + g_Y$
u up quark	1	1/2	1/6	2/3
d down quark	1	-1/2	1/6	-1/3
ν neutrino	0	1/2	-1/2	0
e^- electron	0	-1/2	-1/2	-1

Pattern repeats for 3 “generations”

Not fully understood at present

Home Page

Title Page

Contents

◀ ▶

◀ ▶

Page 7 of 14

Go Back

Full Screen

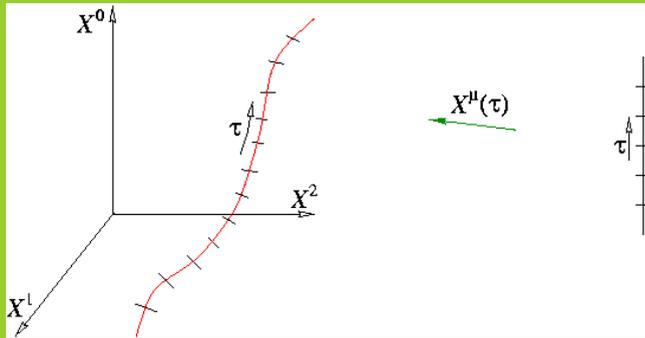
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Quit

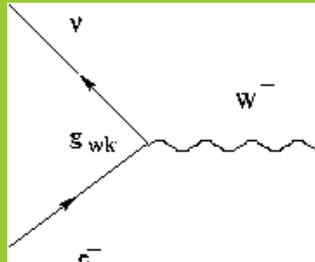
All of this well packaged into ...

The particle picture

Feynman spacetime picture



Building blocks of scattering



Home Page

Title Page

Contents

◀ ▶

◀ ▶

Page 8 of 14

Go Back

Full Screen

Close

Quit

“What about Gravity?”

... Abdus Salam

An ultra-universal theory

$$\frac{G_N M m}{r^2} = m a$$

Effect of gravity purely geometrical

$m_{Grav} = m_{inertial}$ “Principle of Equivalence”

Dynamics of Gravity determined by the **geometric** principle

$$\frac{1}{16\pi G_N} \int_{space-time\ domain} (\text{Riemann curvature}) = \text{extremum}$$

Gravity field \equiv space-time geometry

[Home Page](#)

[Title Page](#)

[Contents](#)

[◀](#) [▶](#)

[◀](#) [▶](#)

Page 9 of 14

[Go Back](#)

[Full Screen](#)

[Close](#)

[Quit](#)

Peculiarities of Gravity

- No known “charge quantization”.
- Gravity field itself difficult to quantize
 - The particle picture (recall Feynman diagram) applied to Gravity results in an indeterminate Quantum Theory.
- Fundamental scale of gravity far different from that of the other interactions.

$$G_N \sim (10^{19} GeV)^{-2} \quad G_{wk} \sim (2 \times 10^2 GeV)^{-2}$$

Biggest hinder to unification

Home Page

Title Page

Contents

◀▶

◀▶

Page 10 of 14

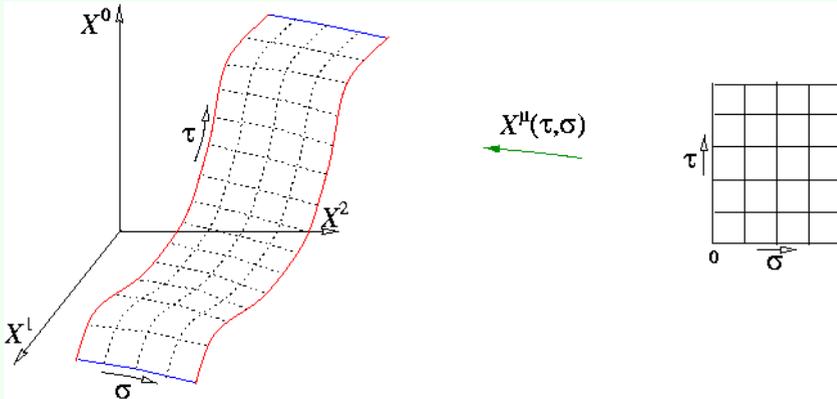
Go Back

Full Screen

Close

Quit

Enter String



Dynamics determined by the **geometric** principle :

$$\int d(\text{Area traced}) = \text{extremum}$$

Suffices to determine

- Fundamental particles with quantized charges
- All the interactions among them in accordance with the gauge principle

Home Page

Title Page

Contents

◀ ▶

◀ ▶

Page 11 of 14

Go Back

Full Screen

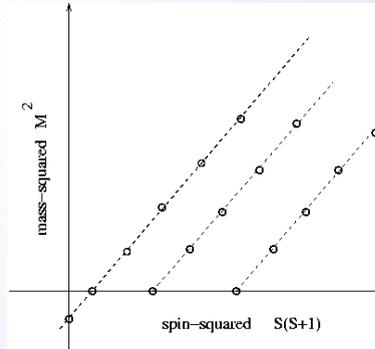
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Quit

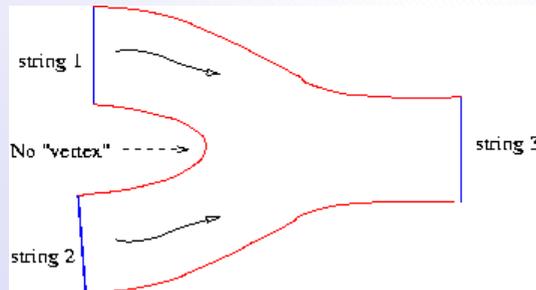
Two in one

universality and unification

List of fundamental particles



Geometric coupling : minimal area condition



[Home Page](#)

[Title Page](#)

[Contents](#)

[◀](#) [▶](#)

[◀](#) [▶](#)

Page 12 of 14

[Go Back](#)

[Full Screen](#)

[Close](#)

[Quit](#)

Uniqueness of Strings

- Quantum consistency only for
 - only for 26 space-time dimensions for bosonic String or 10 dimensions for Supersymmetric (boson-fermion symmetric) string
 - only for certain gauge symmetry groups for the particle interactions
- Quantum theory well behaved
- Only known way to unify all fundamental forces including Gravity

[Home Page](#)

[Title Page](#)

[Contents](#)

[◀](#) [▶](#)

[◀](#) [▶](#)

Page 13 of 14

[Go Back](#)

[Full Screen](#)

[Close](#)

[Quit](#)

Successes and potential

- Black Hole physics involves strong Gravity. It can be consistently understood.
- Big Bang is another strong Gravity phenomenon. All cosmological puzzles can be addressed within this framework.
- Space-time are dynamically generated. Dimensionality is selected.
- Number of fermion generations has fundamental explanation

Much progress : Economy and elegance of concepts
Nature the final judge

[Home Page](#)

[Title Page](#)

[Contents](#)

[◀◀](#) [▶▶](#)

[◀](#) [▶](#)

Page 14 of 14

[Go Back](#)

[Full Screen](#)

[Close](#)

[Quit](#)