

# Overview of String Theory Phenomenology

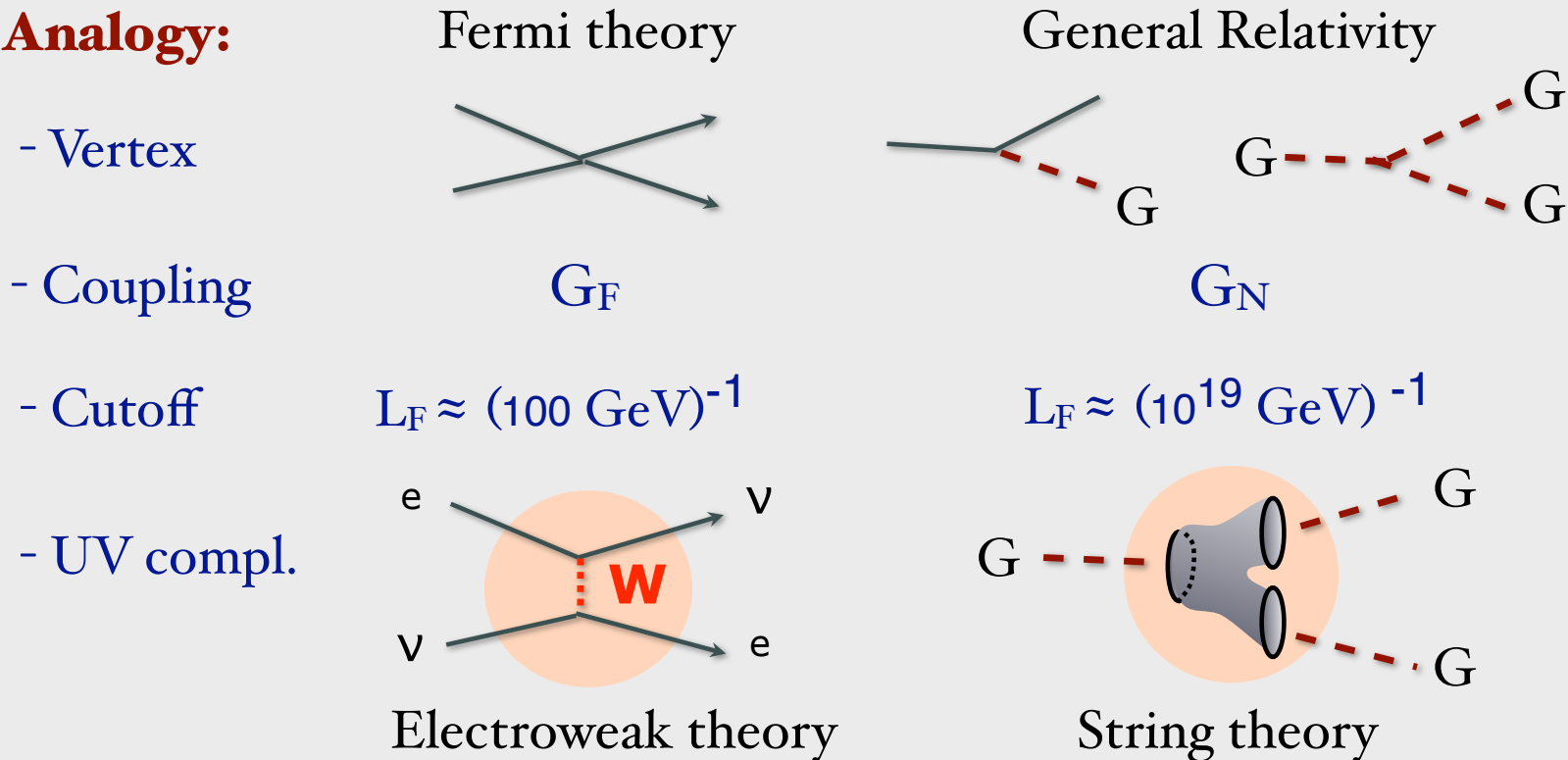
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TH retreat, November 2009

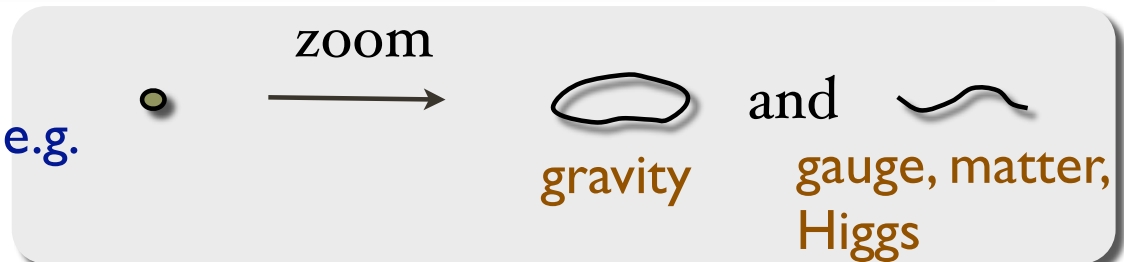
# String theory

- Reconcile gravity with rules of Quantum Mechanics.
- General Relativity as effective field theory, UV completed by string theory

## Analogy:

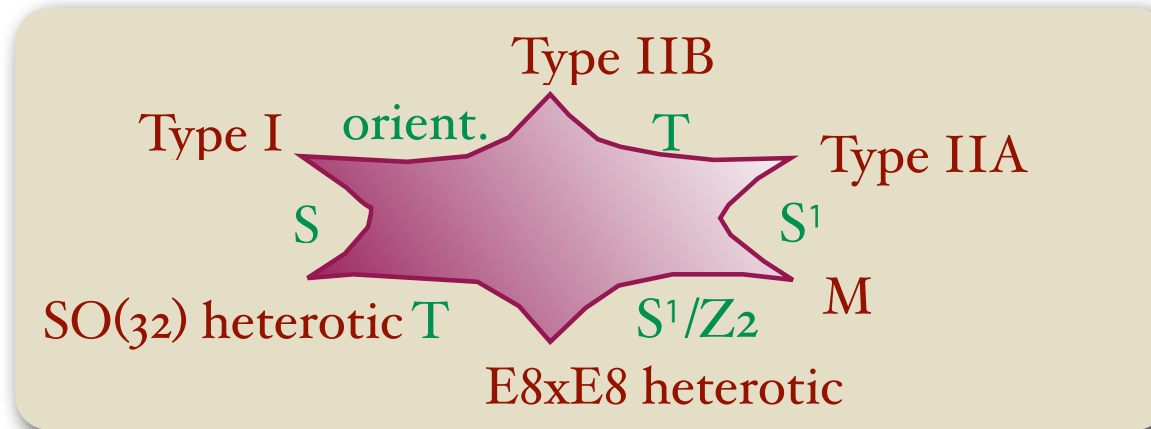


Elementary particles are oscillation modes of strings, e.g.



# String theory: Unity & diversity

- Formulated in 10d, string theory is a remarkably unique theory of gravity and gauge interactions

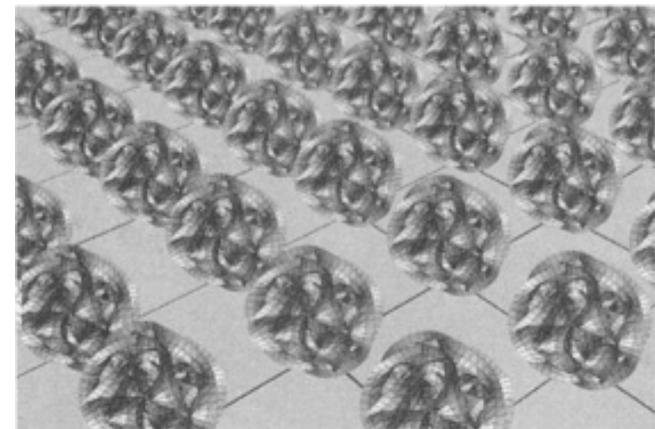


- But need to ‘compactify’ 6 dimensions in small finite size geometry

Spacetime  $M_4 \times X_6$

- Far from unique, and each choice of compactification space leads to different 4d physics

Analogy with General Relativity:  
Unique set of equations, but many solutions



# String Phenomenology

📌 If string theory is realized in Nature, it should be able to describe a very specific gauge sector: **Standard Model**

📌 **Aim of String Phenomenology:**

- Determine classes of constructions with a chance to lead to SM

Non abelian gauge interactions, replicated charged fermions, Higgs scalars with appropriate Yukawa couplings, ...

(Extensive use of techniques in formal theory)

- Within each class, obtain explicit models as close to SM as possible with the hope of learning more about the high energy regime of SM in string theory

📌 Old program, yet continuous progress

📌 **Huge field: Focus on few subtopics**

- SM model building

F. Marchesano's talk

- Moduli stabilization

P.G. Camara's talk

-Non-perturbative effects

M. Schmidt-Sommerfeld's talk

-Susy breaking

M. Buican's talk

# D-brane models & the gauge sector

cf. Fernando's talk

Some of most successful setups to realize the SM is based on D-branes

High-dim. planes on which open strings end

• **Brane world: Partial “decoupling”**

- Closed strings: gravity in 10d
- Open strings: gauge+matter on brane

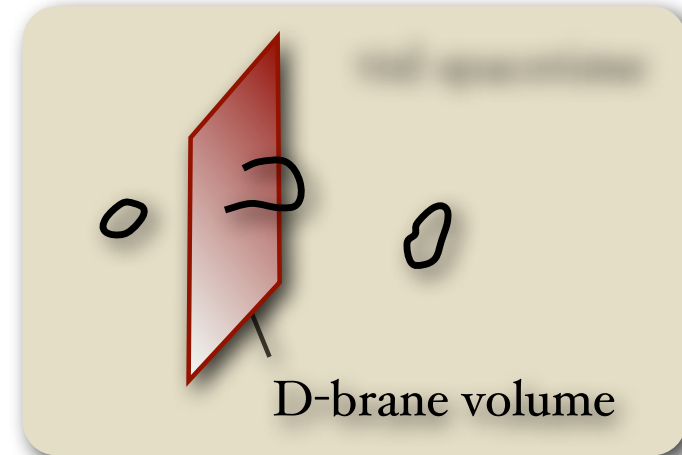
• **Allows large extra dimensions**

$$M_P^2 g_{SM}^2 = \frac{M_s^{11-p} V_\perp}{g_s}$$

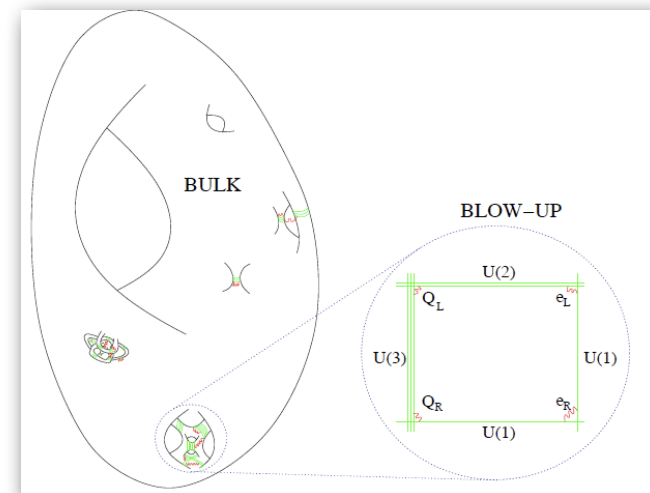
• **Global  $\Leftrightarrow$  local:**

Allows focusing on local models as initial step before dealing with full compactification

• **Geometrization of SM features**



[Antoniadis, Arkani-Hamed, Dimopoulos, Dvali '98]



# Moduli stabilization & the gravity sector

cf. Pablo's talk

What fixes geometry of compactification space?

Free parameters in the compact geometry are massless fields in 4d (moduli')

Phenomenological disaster!

5th forces, cosmological problems,...

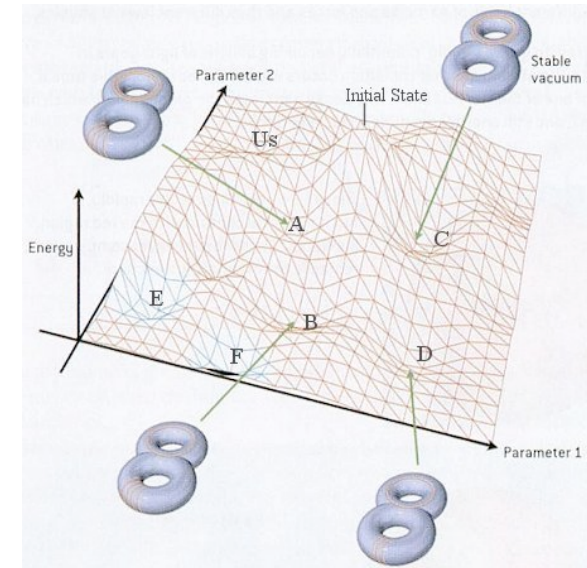
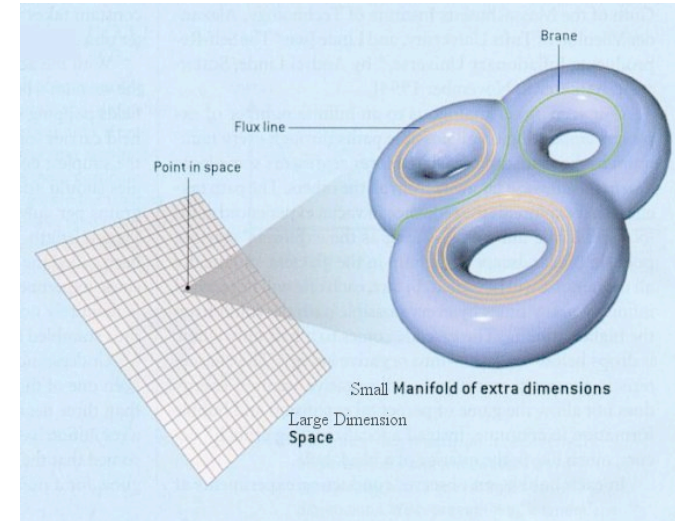
Turn on magnetic fluxes in compact space

Generalized gauge potentials in gravity sector

Interesting effects:

- Flux energy depends on geometry:  
Stabilization by energy minimization

- Fluxes gravitate: warped dimensions  
[Randall, Sundrum '99]



## Life at the interface

Important ingredients arise in global models, with effect on local D-brane patch

### Non-perturbative instanton effects

cf. Max's talk

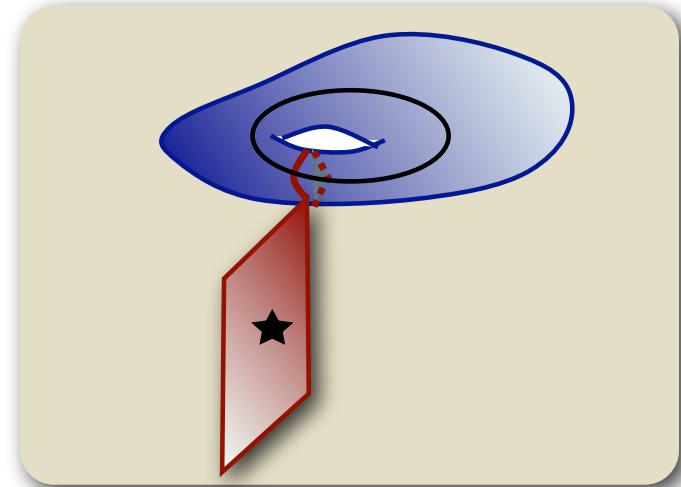
Instanton effects (from D-branes with all dimensions wrapped on internal space) can

- Modify scalar moduli potential and help in moduli stabilization
  - Induce perturbatively forbidden couplings in SM brane system
- Useful: Yukawas,  $\mu$  term, ... or dangerous: R-parity violation

### Supersymmetry breaking

- Supersymmetry breaking fluxes can induce soft terms in susy branes
- Instanton effects can catalyze mechanisms of dynamical supersymmetry breaking or its mediation

cf. Matthew's talk



# What is it good for?

 Many realistic-looking vacua: No unique testable prediction

Each particular consistent realistic model is probably wrong

But some general lessons may be right and key to the UV of SM

- New scenarios (in UV complete theory):

Extra dimensions, brane world, warping, ...

- Plausible patterns within each scenario

e.g. Low energy susy and susy breaking soft terms

- Smoking guns for some scenarios ( $\pm$ contrived)

e.g. string resonances in TeV scale models

 To be continued in next talks