SUPERSYMMETRY BREAKING WITH FIELDS, STRINGS AND BRANES

PRIN 2017

SNS Pisa, 18/10/2019
PRIN kick-off meeting

SUPERSYMMETRY BREAKING WITH FIELDS, STRINGS AND BRANES

Carlo Angelantonj
(UNITO & INFN)

SNS Pisa, 18/10/2019
PRIN kick-off meeting

SUPERSYMMETRY BREAKING WITH FIELDS, STRINGS AND BRANES

Based on collaborations with:

I. Antoniadis, M. Cardella, E. Dudas, S. Elitzur, I. Florakis,
K. Förger, N. Irges, K. Kounnas, H. Partouche, E. Rabinovici,
A. Sagnotti, N. Toumbas, M. Tsulaia

As of today, we don't have any evidence of supersymmetry in Nature

Supersymmetry, if present, must be (spontaneously) broken at suitable energy scales

To avoid the swampland we break supersymmetry with ***strings*** *and* ***branes***

WAYS TO BREAK SUPERSYMMETRY

Coordinate Dependent Compactifications ❶

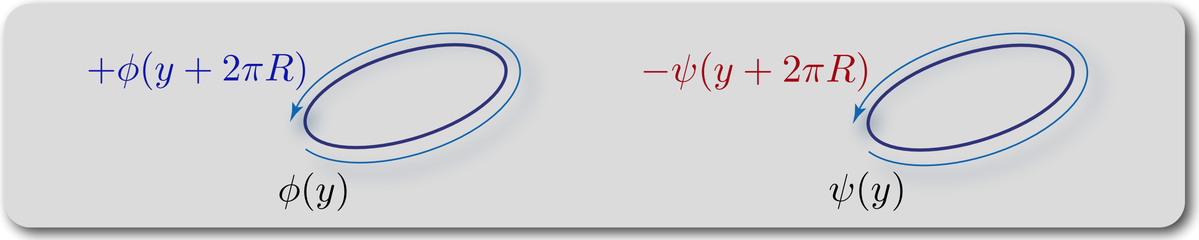
Brane Supersymmetry Breaking ❷

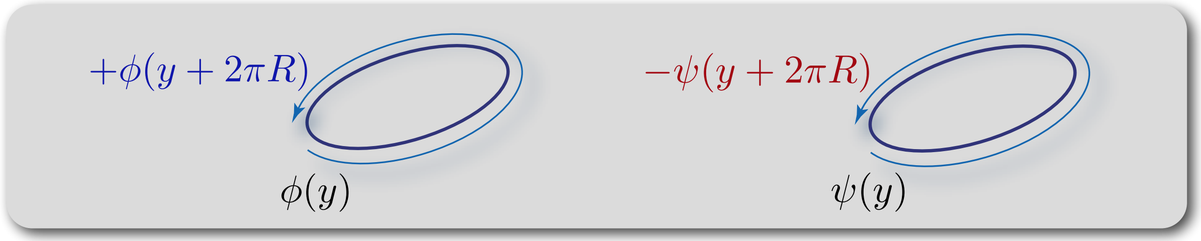
COORDINATE DEPENDENT COMPACTIFICATIONS

Scherk-Schwarz compactification is an elegant way of breaking supersymmetry via compactification

Use symmetries of the action to impose different periodicities for fields in a given supermultiplet

For instance, upon reducing on a circle of radius R





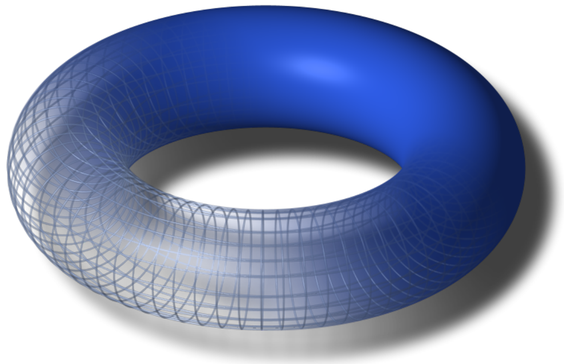
The different boundary conditions clearly affect the KK frequencies

$$\phi(y) = \sum_{n\in\mathbb{Z}} \phi_n \, e^{iny/R} \qquad\qquad \psi(y) = \sum_{n\in\mathbb{Z}} \psi_n \, e^{i(n+\frac{1}{2})y/R}$$

so that bosons and fermions have got different masses

$$M_\phi^2 = M_0^2 + \left(\frac{n}{R}\right)^2 \qquad\qquad M_\psi^2 = M_0^2 + \left(\frac{n+\frac{1}{2}}{R}\right)^2$$

String Theory is more constrained than Field Theory, and thus any modification of the spectrum must be subjected to the conditions of modular invariance of the one-loop vacuum amplitude.



It turns out that potential tachyonic instabilities may emerge

$$\mathscr{Z} \sim \int_{\mathscr{F}} \frac{d^2\tau}{\tau_2^{11/2}} \frac{1}{|\eta|^{16}} \sum_{m,n} \Big[(V_8\bar{V}_8 + S_8\bar{S}_8)\Lambda_{m,2n} - (V_8\bar{S}_8 + S_8\bar{V}_8)\Lambda_{m+\frac{1}{2},2n} + (O_8\bar{O}_8 + C_8\bar{C}_8)\Lambda_{m,2n+1} - (O_8\bar{C}_8 + C_8\bar{O}_8)\Lambda_{m+\frac{1}{2},2n+1} \Big]$$

$$M^2 = -1 + \tfrac{1}{2}R^2$$

The radius of the circle sets the scale of supersymmetry breaking. A SUSY spectrum is recovered in the infinite R limit

In gravity, the radius R is a dynamical field, and one should study its dynamics to ensure the stability of the construction

The Scherk-Schwarz compactification
is applicable to any string theory:

type II, heterotic and type I

It has a clear description in terms of the
low-energy supergravity

QUANTUM PROPERTIES

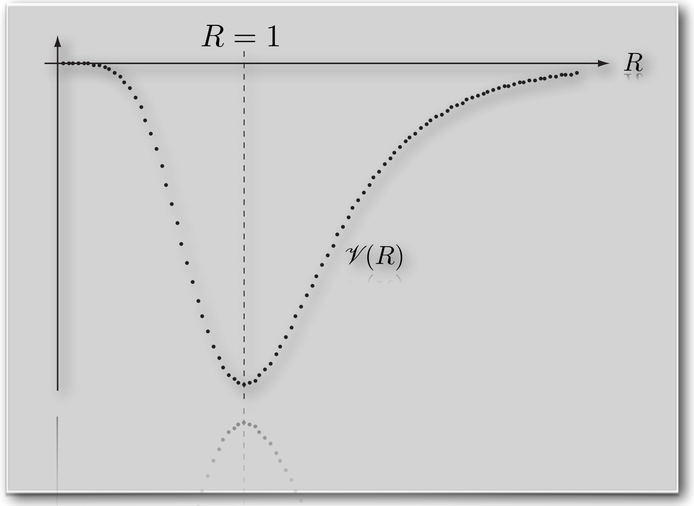
Classically, the Scherk-Schwarz compactification is described by a no-scale supergravity

Radiative corrections break this description

$$V(R) = \frac{n_F^{(0)} - n_B^{(0)}}{R^4} + \mathcal{O}(e^{-R})$$

Quantum-no-scale models: $n_F^{(0)} - n_B^{(0)} = 0$

[Abel, Dienes; Faraggi, Kounnas, Partouche]



[C.A., Cardella, Irges]

QUANTUM PROPERTIES

One loop corrections to gauge couplings:

$$\frac{16\pi^2}{g_\alpha^2(\mu)} = \frac{16\pi^2}{g_s^2} + \beta_\alpha \log\frac{M_s^2}{\mu^2} + \Delta_\alpha$$

light states

heavy states

Unexpected ***universality*** in the difference of gauge thresholds

$$\Delta_\alpha - \Delta_\beta = a \log\left[T_2 U_2 |\eta(T)\eta(U)|^4\right] + b \log\left[T_2 U_2 |\vartheta_4(T)\vartheta_2(U)|^4\right] + c \log|j_\infty(T/2) - j_\infty(U)|^4$$

[C.A., Florakis, Tsulaia]

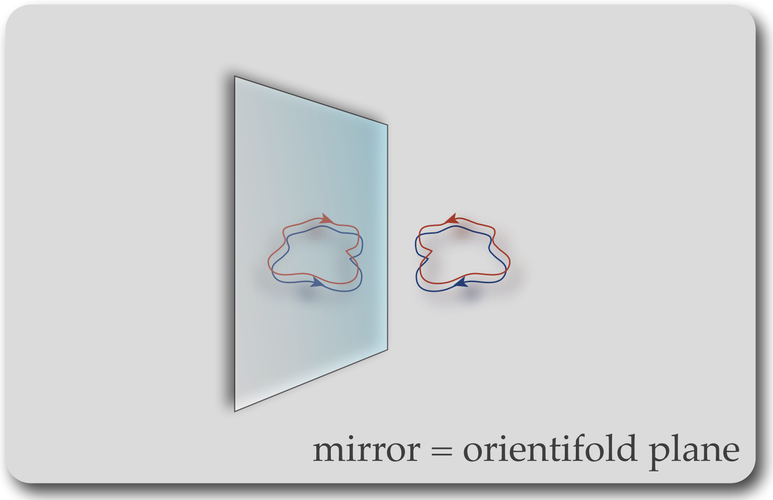
BRANE SUPERSYMMETRY BREAKING

[Sugimoto; Antoniadis, Dudas, Sagnotti]

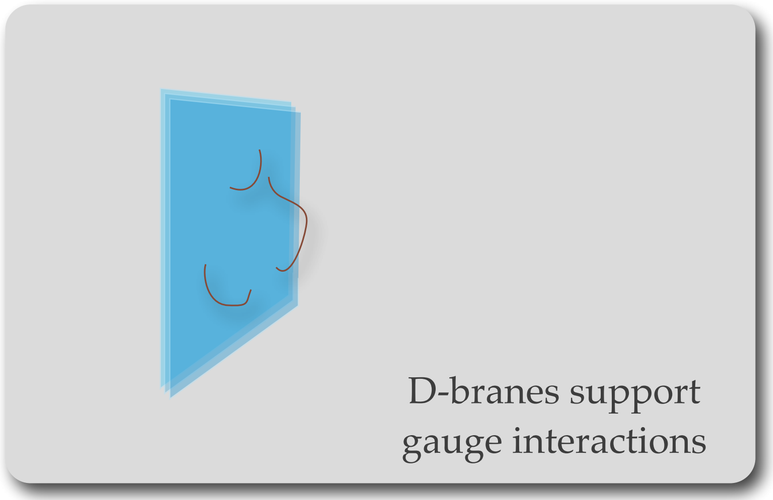
As the name suggests,
it takes place in orientifold models
with branes and orientifold planes

It does not have a counterpart
in heterotic strings

ORIENTIFOLDS IN A NUTSHELL



mirror = orientifold plane



D-branes support gauge interactions

	Tension	*Charge*
Op_+	-32	-32
Op_-	32	32
Dp	1	1

anti-objects have reversed charge

TADPOLE CONDITIONS

Consistency requires

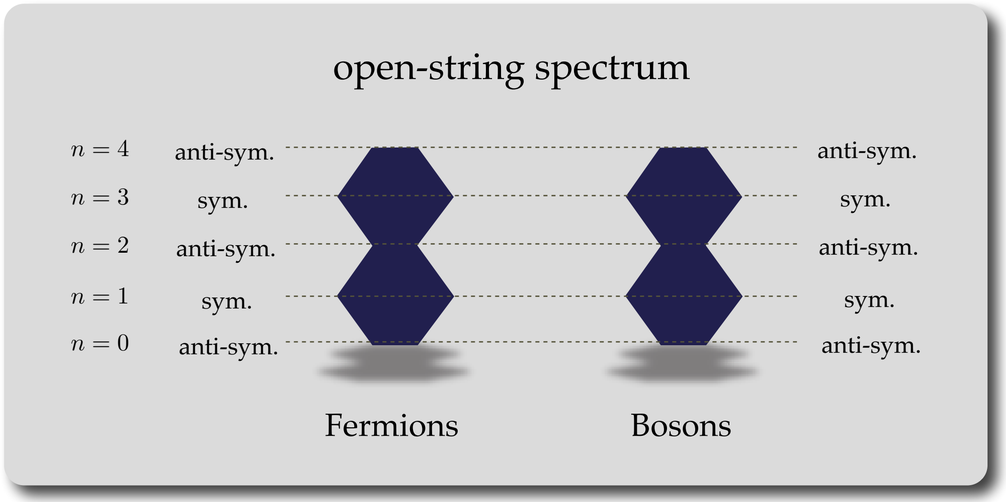
$$Q_O + Q_D = 0$$

Stability requires

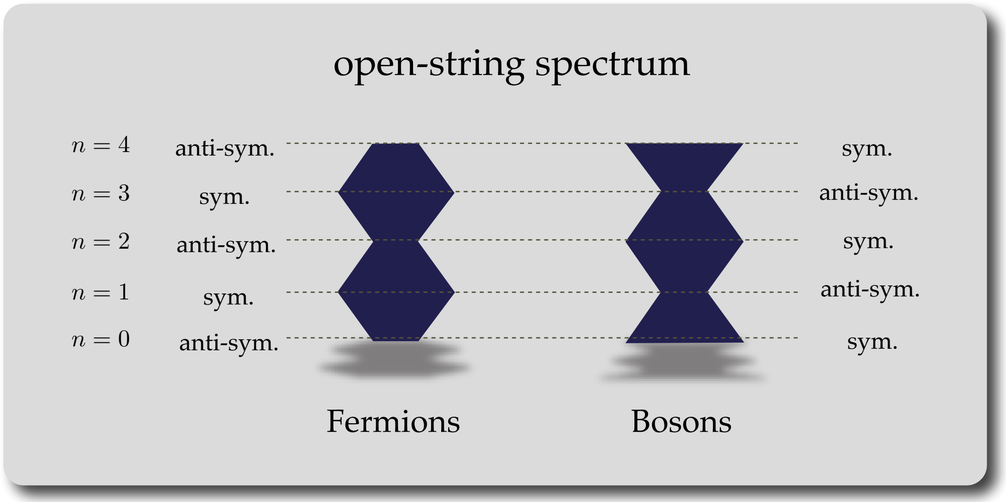
$$T_O + T_D = 0$$

Already in D=10 there are two options:

Supersymmetric type I superstring G=SO(32)



Brane Supersymmetry Breaking G=USp(32)



Supersymmetry is hardly broken (in open strings) at the string scale!

Tree-level dilaton tadpole

BRANE SUPERSYMMETRY BREAKING

Although in D=10 BSB is optional,
in lower dimensional orientifolds it can be
the **only** consistent possibility

$T^4/\mathbb{Z}_2$ with 17 tensor multiplets

[Antoniadis, Dudas, Sagnotti]

See [Blum, Zaffaroni] for a SUSY construction with 17 tensors

$T^6/\mathbb{Z}_4$

[C.A., Antoniadis, D'Appollonio, Dudas, Sagnotti]

2

BRANE SUPERSYMMETRY BREAKING

Low-energy dynamics in terms of
non-linearly realised supersymmetry

[Dudas, Mourad]

1

Scherk-Schwarz Mechanism

Applicable to any String Theory

No-scale supergravity

The compactification radius is the order parameter

2

Brane Supersymmetry Breaking

Only in orientifold vacua

Supersymmetry is non-linearly realised *a la* Volkov-Akulov

The string tension sets the scale of supersymmetry breaking

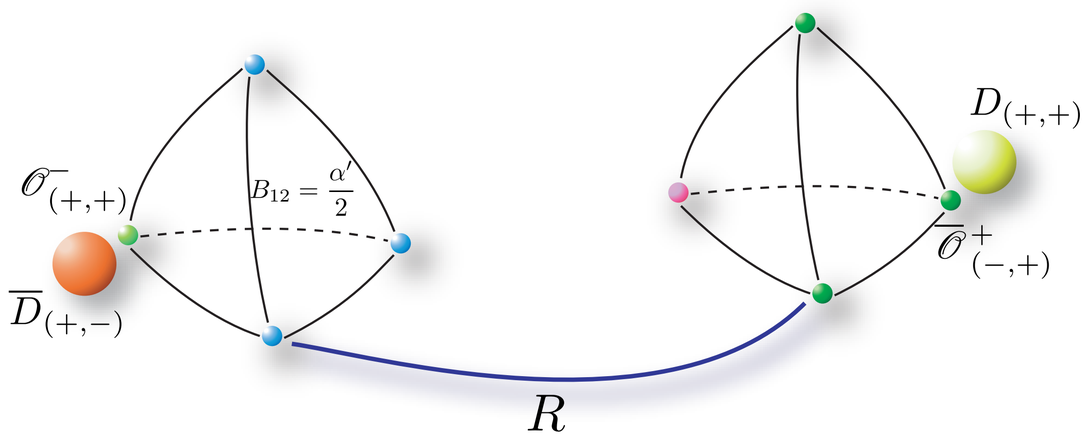
❶+❷=Disentangling Scales

[C.A., Antoniadis; C.A. Cardella]

open spectrum

$USp(8)$

$\psi' \in \underline{28}$



open spectrum

$SO(8)$

$\psi \in \underline{36}$

Cosmological constant scale: $\Lambda \sim R^{-4}$

Gaugino mass scale: $M_{\text{gaugino}} \sim 1/\sqrt{\alpha'}$

OPEN PROBLEMS

OPEN PROBLEM

ALL WAYS TO BREAK SUPERSYMMETRY
(WITH STRINGS AND BRANES!)
HAVE A COMMON FEATURE:

THE EMERGENCE OF DILATON TADPOLES.

WHAT IS THE NEW VACUUM?
HOW TO MOVE TO THE NEW VACUUM?
HOW TO CURE IR DIVERGENCES?

WHAT IS THE NEW (CLASSICAL) VACUUM FOR BSB?

Many attempts to answer this question

Spontaneous compactification from D=10 to D=9?

[Dudas, Mourad]

Adding fluxes: $AdS_3 \times S^7$ or $AdS_7 \times S^3$

[(Basile),Mourad, Sagnotti]

What about their (in)stability or validity?

THANK YOU!