Stable D7 embeddings in walking backgrounds

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in progress

(with P. Suranyi, L.C.R. Wijewardhana)

also relevant: arXiv:1006.3570 [hep-th]; arXiv:1105.4185 [hep-th]

arXiv:1203.1968 [hep-th]

Goal:

To study Dynamical Mass Generation

Possible pheno application:

Dynamical electroweak symmetry breaking

(Strongly-coupled gauge dynamics $\rightarrow$ composite Higgs)

Advantage: natural (no hierarchy problem)

(compared to fund. Higgs)

Disadvantage: Strong coupling is a challenge for standard QFT methods!

Gauge/Gravity Duality

(AdS/CFT correspondence)

New non-perturbative method:

Some strongly coupled Quantum Field Theories have an equivalent (called dual) description in terms of weakly coupled Gravity Backgrounds in a different number of dimensions.

QFT $\longleftrightarrow$ Gravitational solution

strong coupling — weak coupling

Gauge/Gravity Duality

(AdS/CFT correspondence)

Basic ingredients of Gravity Dual:

- supersymmetric brane sources

  (color degrees of freedom)

- non-supersymmetric probe branes

  (flavour degrees of freedom)

$\Rightarrow$ Can have tachyonic mode(s).

How can we remove it (them)?

Plan

– Gravity Duals of Chiral Symmetry Breaking

(a la Sakai-Sugimoto)

– Walking Technicolor

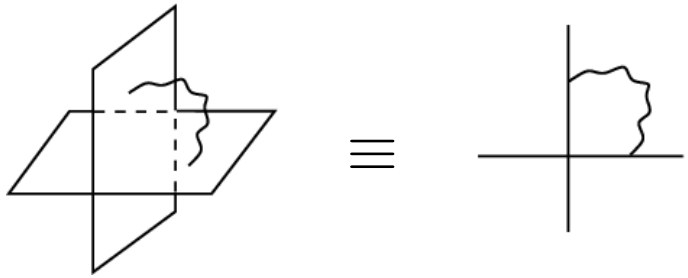
- Basic Ingredients
- Instability in flavour (probe D7) sector
- Stabilizing the D7 embedding

– Summary and Outlook

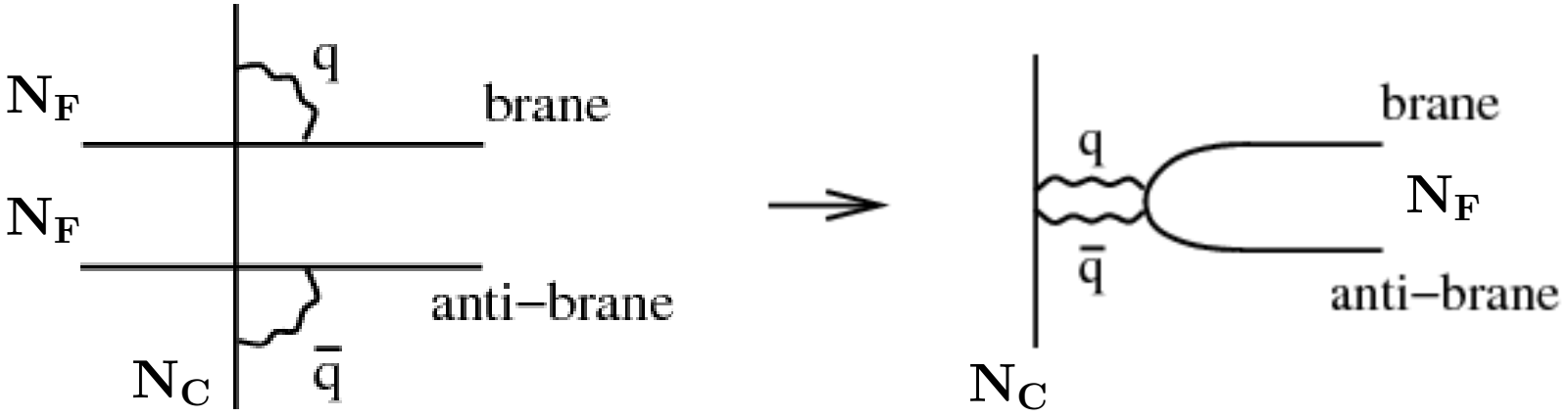
Gravity Duals of Chiral SB

Need chiral fermions $\rightarrow$ consider intersecting D-branes

Shorthand notation:



Chiral symmetry breaking: [Sakai and Sugimoto (2004)]



both chiralities

chiral sym. breaking: $\langle \bar{q}q \rangle \neq 0$

Gravity Duals of Chiral SB

Intersecting branes:

In practice: Very difficult to find full gravitational solution for intersecting D-branes!

So often:

Use approximation: Treat flavour branes as probes in background sourced by color branes.

(i.e., $\mathbf{N_F} \ll \mathbf{N_C}$)

$\Rightarrow$ QFT: In different universality class compared to $\mathbf{N_F} \sim \mathbf{N_C}$ models.

Walking Technicolor

Need two ingredients:

- Background sourced by a stack of N_{TC} branes
- U-shaped embedding of N_{TF} probe branes in above background

Chiral symmetry breaking:

U-shape: $SU(N_{TF})_L \times SU(N_{TF})_R \rightarrow SU(N_{TF})_D$

Electroweak symmetry breaking:

Induced via $[SU(2) \times U(1)]_{EW} \subset SU(N_{TF})_L \times SU(N_{TF})_R$

Walking Technicolor

Technicolor background:

[Nunez, Papadimitriou and Piai (2008)]

Solution of IIB Supergravity equations of motion,

due to N_{TC} D5 branes wrapping an S^2.

[10 dim. metric and RR 3-form flux]

- Deformation of famous Maldacena-Nunez solution
- BUT: dilaton is constant

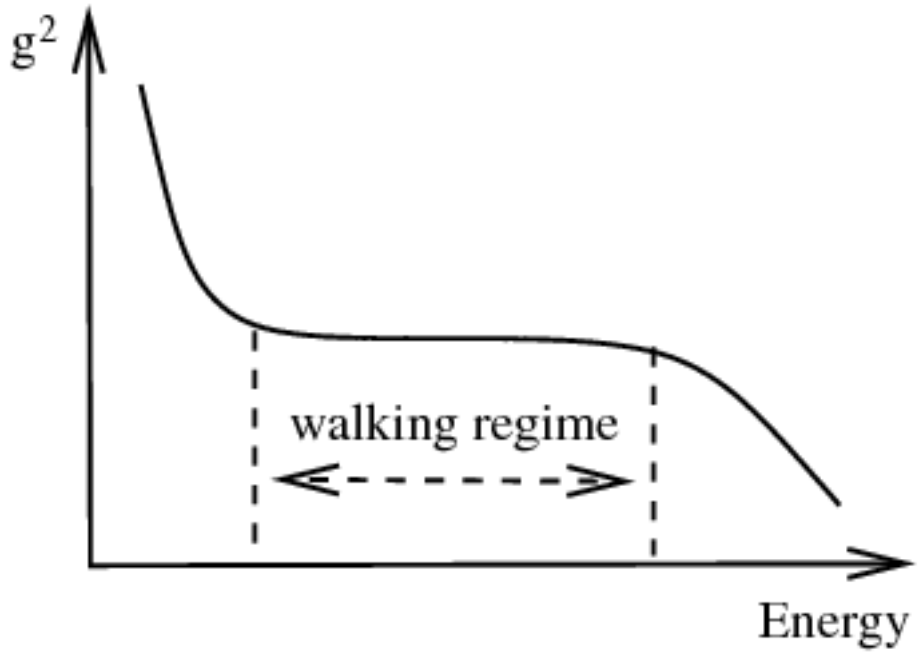
[Note: Dilaton is not gauge coupling!]

Walking Technicolor

Technicolor background:

Solution depends on two parameters.

In certain parameter range: walking gauge coupling



Walking Technicolor

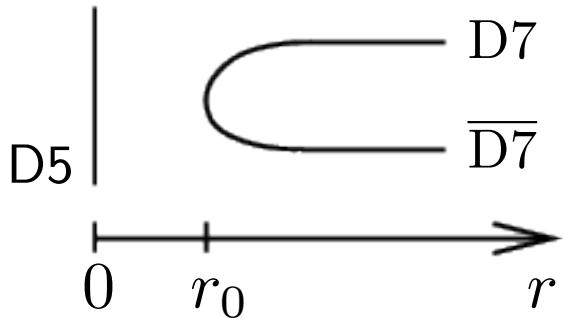
Techniflavour probe branes: [LA (2010)]

D7 – anti-D7 probes in above D5 background

	0	1	2	3	4	5	6	7	8	9
backgr D5:	×	×	×	×	×	×				
probe D7 - $\overline{\text{D7}}$:	×	×	×	×			×	×	×	×

4d Mink. S^3 r

There is a U-shape embedding:



Walking Technicolor

Meson spectrum:

- Vector mesons (arise from fluctuations of worldvolume field)
- Scalar mesons (arise from fluctuations of $\mathrm{D7}$ - $\overline{\mathrm{D7}}$ embedding)

Since $\mathrm{D7}$ - $\overline{\mathrm{D7}}$ embedding is not supersymmetric, there is no guarantee that $m^2 > 0$ for all states.

$\rightarrow$ To show perturbative stability, have to compute the spectrum explicitly.

Walking Technicolor

Vector mesons:

[LA, Suranyi and Wijewardhana (2011)]

Computed: $m^2_{V_n},\, m^2_{A_n} > 0$ at every level n

$$\Rightarrow \qquad S = 4\pi \sum_{n=1}^{\infty} \left(\frac{g^2_{V_n}}{m^4_{V_n}} - \frac{g^2_{A_n}}{m^4_{A_n}} \right), \qquad \begin{array}{l} V \text{ - vector} \\ A \text{ - axial-vector} \end{array}$$

g_n - decay constants

Found: $S > 0$ and small !

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Scalar mesons:

[LA, Suranyi and Wijewardhana (2012)]

[Clark, Love and ter Veldhuis (2012)]

Arise from fluctuations of $\mathrm{D7}$ - $\overline{\mathrm{D7}}$ embedding.

2 embedding functions $\Rightarrow$ 2 types of scalar mesons, φ and θ

Found:
- $m^2_{\theta_n} > 0$ at every level n
- lowest φ-mode has $m^2_\varphi < 0$!

Walking Technicolor

Scalar mesons:

[LA, Suranyi and Wijewardhana (2013 - in progress...)]

Two ways to stabilize the $\mathrm{D7}$ - $\overline{\mathrm{D7}}$ embedding:

- Turn on world-volume flux

$$F_{r\,\tilde{\omega}_3} = const \quad , \quad \tilde{\omega}_3 = d\psi + \cos\tilde{\theta} d\tilde{\varphi} \quad ,$$

$(\psi, \tilde{\theta}, \tilde{\varphi})$: S^3 wrapped by $\mathrm{D7}$

$\rightarrow \quad \theta(r) = \frac{\pi}{2}$ - same , $\varphi(r)$ - changed

Walking Technicolor

Scalar mesons:

[LA, Suranyi and Wijewardhana (2013 - in progress...)]

Two ways to stabilize the $\mathrm{D7}$ - $\overline{\mathrm{D7}}$ embedding:

- Modify embedding functions

Both functions $\theta(r)$ and $\varphi(r)$ - nontrivial,

No world-volume flux

in progress...

Summary

Considered a model of dynamical mass generation.

Gravitational dual contains non-susy D7 probe branes

$\Rightarrow$ instabilities could exist

Found:

- no tachyons in vector meson spectrum
- a tachyonic mode in scalar spectrum !
- tachyon mode can be removed by:
  - world-volume flux
  - modified embedding functions

Thank you!