Holographic Gauge Mediation*

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* work in progress with S. Franco, S. Kachru, D. Simic, and A. Dymarsky

- Motivation
- General Set Up: GGM
- Gravity Dual
- Single Sector Model
- Conclusion

Why do string phenomenology?

- Top-Down: Answer UV sensitive physics questions.
- Bottom-Up: Correspondence Principle (decouple M_{pl})
- As a tool to study strongly coupled gauge dynamics.

Imagine that LHC finds evidence for the presence of a

strongly coupled hidden sector:

- **models with composite Higgs, quarks, etc**
- **gauge mediation with strongly coupled messengers**
- **hidden valley models, or unparticles**
- ...

The hidden sector couples to the visible fields via

stress tensor, currents, composite operators

$$T^{\text{h}}_{\mu\nu}\, h_{\mu\nu} \;+\; J^{\text{h}}_{\mu}\, A_{\mu} \;+\; \mathcal{O}^{\text{h}}_{i}\, \phi_i \;+\; \ldots$$

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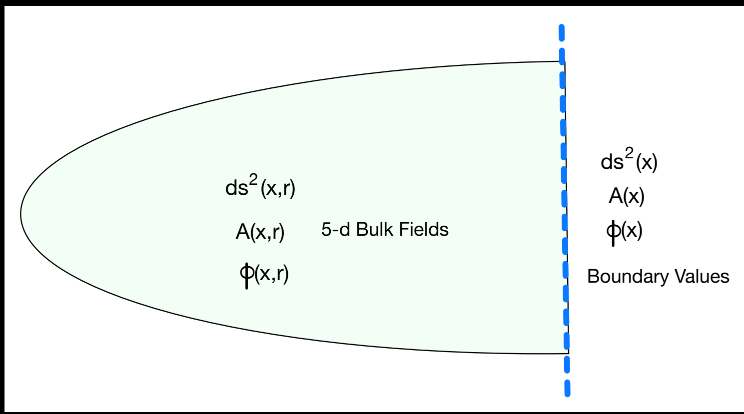
The hidden sector has a mass gap m and UV cut-off Λ.

- If $m \gg$ TeV, we can integrate out the hidden sector fields. The visible imprint can be extracted from the n-point functions of the hidden sector operators. Renormalizes the visible action, and adds extra tems – e.g. soft SUSY parameters.

- If $m \sim$ TeV, hidden particles may be produced at the LHC, and need to be included in the dynamics. Leads to missing energy, partial compositeness, etc.

Let us imagine that the hidden sector has a geometric dual:

$$\left\langle e^{i\int(T^{h}_{\mu\nu}\, h_{\mu\nu} + J^{h}_{\mu}\, A_\mu + \mathcal{O}^{h}_{i}\, \phi_i)} \right\rangle \simeq e^{iS_{\text{sugra}}(h,A,\phi)}$$



$$S_{\text{sugra}}(h,A,Q) = \int\sqrt{-g}\,(a\,R + b\,F^2_{\mu\nu} + c\,(\partial\phi)^2 + \ldots)$$

Holographic RG

The visible 4-d fields $(h_{\mu\nu}, A_\mu, \phi_i)$ live on the "UV brane"
$\rightarrow$ correspond to boundary values of the 5-d bulk fields.
The total 4-d action splits into:

$$S_{4-d} = S_{\text{bare}}(h,A,\phi) + S_{\text{sugra}}(h,A,\phi)$$

After turning on the 4-d dynamics, the visible fields therefore mix with the normalizable zero modes of the 5-d bulk fields!

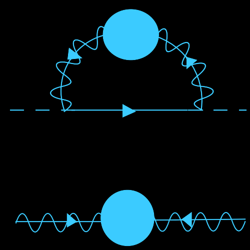
Example: **General Gauge Mediation** Meade, Seiberg, Shih

Hidden sector with DSB, communicates with MSSM via

$$g^2 \int d^4\theta \, \mathcal{J} \, \mathcal{V} \qquad\qquad \mathcal{J} = j_0 + \bar{\theta} \, j_{1/2} + \theta \, \bar{j}_{1/2} + \theta\bar{\theta} \, j_1$$

Soft parameters are extracted from 2-point functions:

$$\begin{aligned} \langle j_0 \, j_0 \rangle &\sim C_0 \,, \\ \langle j_\alpha \, \bar{j}_{\dot\alpha} \rangle &\sim C_{1/2} \sim m^2_{\tilde f} \\ \langle j_\mu \, j_\nu \rangle &\sim C_1 \,, \\ \langle j_\alpha \, j_\beta \rangle &\sim B_{1/2} \sim M_a \end{aligned}$$

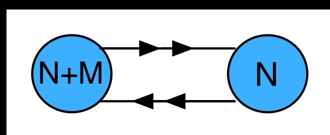


Note: C and B coefficients are proportional to # of messengers N

Gauge theory with metastable DSB and a geometric dual:

KS: $SU(N) \times SU(N+M)$

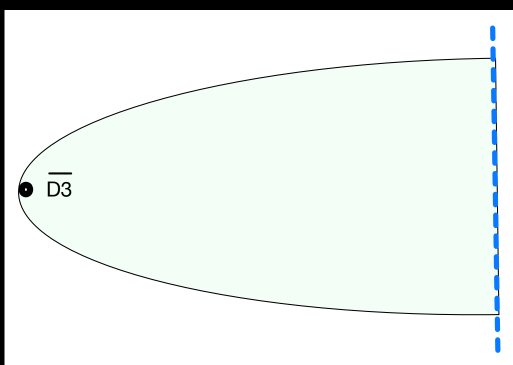
$W = \epsilon^{ij} \epsilon^{kl} A_i B_k A_j B_l$



but with:

$$\boxed{\mathrm{N = KM - p}}$$

Kachru, Pearson, HV

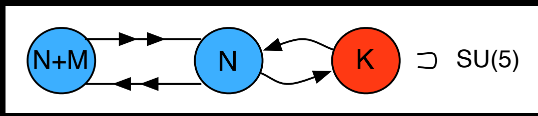


$$z_1^2 + z_2^2 + z_3^2 + z_4^2 = \epsilon^2$$

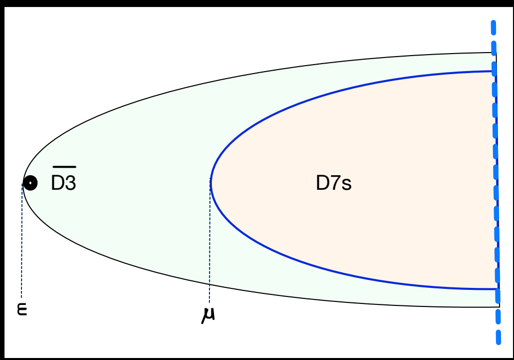
+ normalizable deformation due to anti-D3

Hidden sector needs to have $SU(5)$ global symmetry:

We therefore add $K > 5$ flavor D7-branes:



$$W = \tilde{\varphi}(A_1 B_1 + A_2 B_2)\varphi + \mu\,\varphi\tilde{\varphi}$$



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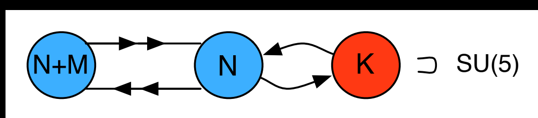

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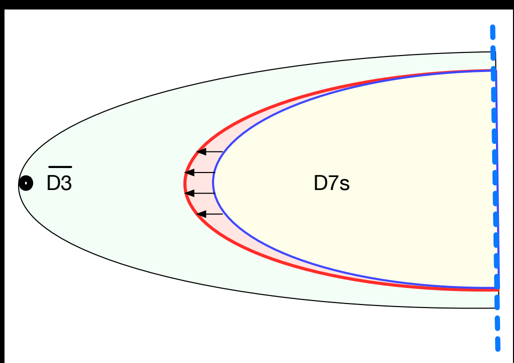

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SUSY-breaking is mediated to the D7-branes via:

a) Open string channel: $\begin{cases} \text{anti-D3} - \text{anti-D3 strings} = \text{non-SUSY} \\ \text{anti-D3} - \text{D7 strings} = \text{messengers} \end{cases}$

$$W = (\mu + X)\,\Phi_{7\bar{3}}\,\Phi_{\bar{3}7} + \frac{1}{2m}(\underbrace{Z_1^2 + Z_2^2 + Z_3^2}_{\text{anti-D3 location}})\,\Phi_{\bar{3}7}\,\Phi_{7\bar{3}}$$

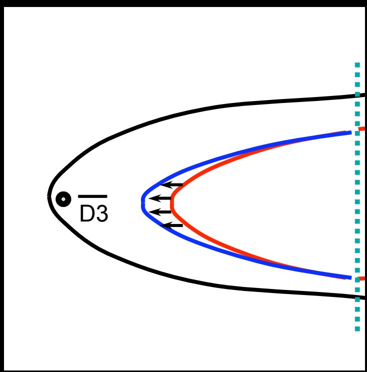
b) Closed string channel: Compute the back-reaction due to the anti-D3 (DeWolfe, Kachru, Mulligan), then compute the small non-SUSY deformation of the D7-brane world volume.

> Both methods produce a 5-d gaugino mass term localized in the IR region of the D7-brane. This mass term generates the soft-SUSY terms via RG running. The set-up is thus expected to give a string realization of (warped) gaugino mediation.

Comments:

Gaugino mediation ↔ Gauge mediation w/ many messengers. Landau pole problem is also present in our model: the D7 can not extend far inside the KS throat.

So far, we imagined that the Higgs and charged MSSM fields live on the UV brane. However, we can also place the light generations in the IR. In 4-d, they become composite, and feel the SUSY breaking more strongly.



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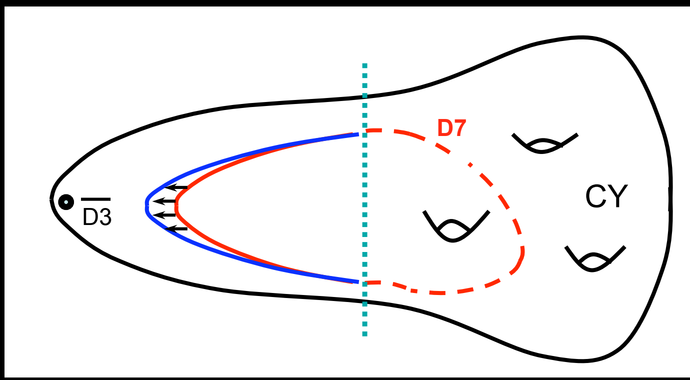
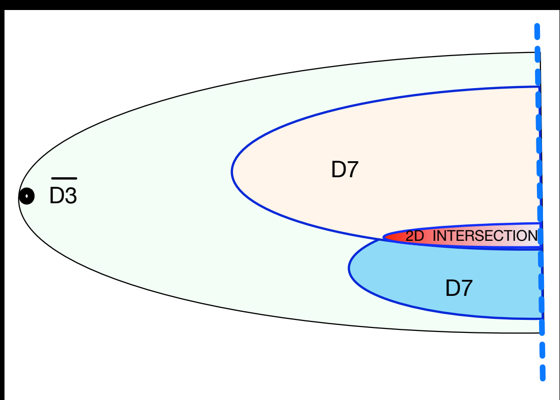


To get charged matter with quantum numbers of the light quarks, we place another set of D7s in the conifold, that intersect with the K D7s. The intersection extends radially, but there exists an open string zero mode that is localized in the IR. Its fermionic component is massless, the scalar acquires a non-zero mass.



Consider two intersecting D7 stacks, described by:

$$(z_1 - \mu_1)^{N_1}(z_2 - \mu_2)^{N_2} = 0$$

We choose z_3 as a coordinate on the intersection Σ. The 77′ open string ground state satisfies an equation of motion of the form

$$\partial\left(\frac{1}{\omega(z_3)}\bar{\partial}\,\Phi\right) = 0$$

where $\omega(z_3)$ is the induced Kahler form on Σ. This eqn can be shown to admit a normalizable solution, localized in the IR.

The non-susy metric, reduced to 5-d, to leading order in M/N and p, and far away from the "tip" region, reads:

DeWolfe,Kachru,Mulligan
c.f. Gabella, Gherghetta,Giedt

$$ds^2 = A^2(z)(-dt^2 + dx_i^2 + dz^2)\,,$$

$$A^2(z) = \frac{1}{(kz)^2}\left(1 - \beta\left(\frac{z}{z_1}\right)^4\right)\,,$$

where

$$k^2 = \frac{2}{\sqrt{g_s\overline{N}}}\,, \qquad \overline{N} = 27\pi N\,,$$

$$\beta = \frac{3\,z_1^4\,\mathcal{S}}{5(g_s\overline{N})^2}\,, \qquad \mathcal{S} = \frac{p}{N}\,\exp\left(-\frac{8\pi N}{3g_s M^2}\right).$$

Here z_1 is the location of the non-susy IR-brane.

A 5-d bulk mode with a radial profile

$$f(z) \propto z^{b-1}$$

is dual to a composite operator $\mathcal{O}$ with scale dimension

$$\Delta(\mathcal{O}) = 4 - b$$

For $b > 1$, the term $\mathcal{O}\,\phi$ is relevant, whereas for $b < 1$ it is irrelevant. IR localized modes with $b > 1$ give rise to composite fields.

GGG have computed the compositeness contribution to the scalar masses. They find (in the limit $kz_1 \gg 1$):

$$\tilde{m}^2 = \frac{\beta\,(b-1)(b+10)}{z_1^2} \qquad b > 1 \quad \text{(IR-localized)}$$

$$\tilde{m}^2 = \frac{\beta}{(kz_1)^{2-2b}}\frac{(1-b)(b+10)}{z_1^2} \qquad 0 < b < 1 \quad \text{(UV-localized)}$$

This expression for the mass contribution has a straightforward 4d RG interpretation. Notice that the scalars localized in the UV receive much smaller masses than their composite cousins.

Conclusion:

• We started the study of a geometric dual of a strongly coupled hidden sector.

• In the dual set-up, SUSY breaking is communicated to the visible fields via a small subset of messengers and the 5-d gaugino.

• We ended up studying the dynamics of D7 branes, and using them to engineer the light generations of matter.

It thus seems natural to try to combine our set-up with the recent insights in F-theory model building.