Scattering in General Gauge Mediation: Vector Meson Dominance and Holography

1207.4484

General Gauge Mediation in 5D

GGM and Deconstruction

Warped General Gauge Mediation

Hybrid Gauge Mediation

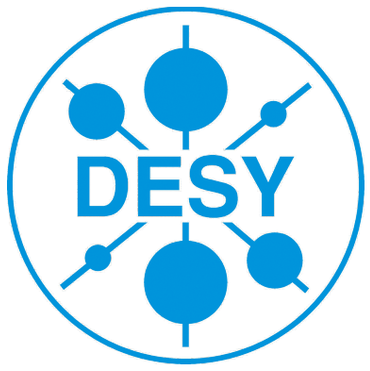
General Resonance Mediation

Holography and General Gauge Mediation

Moritz McGarrie

AvH fellow

host: Andreas Weiler

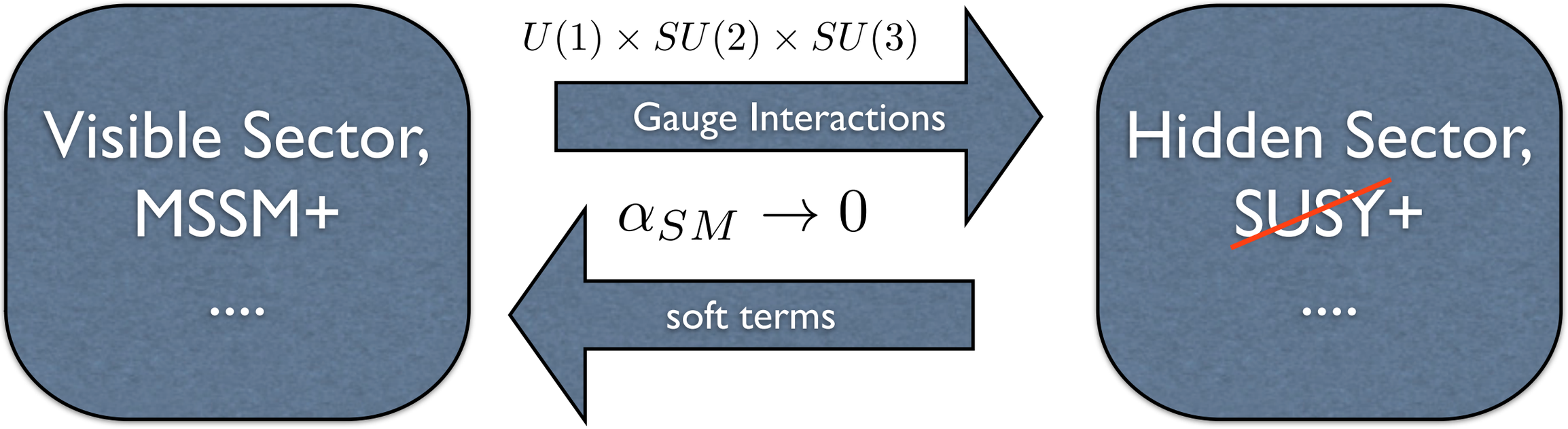


Alexander von Humboldt
Stiftung/Foundation

General Gauge Mediation

Meade, Seiberg, Shih 0801.3278

A model independent framework for gauge mediated supersymmetry breaking



encodes spontaneous breaking in currents

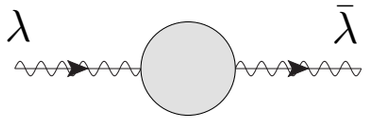
$$\mathcal{L}_{int} = g_{SM}\left(JD + J_\mu A^\mu - j_\alpha \lambda^\alpha - \bar{j}^{\dot{\alpha}} \bar{\lambda}_{\dot{\alpha}}\right)$$

The key point of GGM: we want to understand and encode strongly coupled hidden sectors that break supersymmetry dynamically

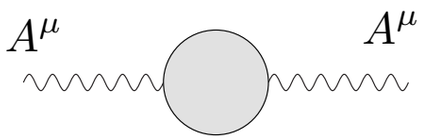
Completely 4D a non perturbative effect solution to hierarchy problem Metastable(ISS)? S matrix ?

The building blocks

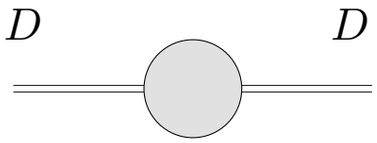
current correlators



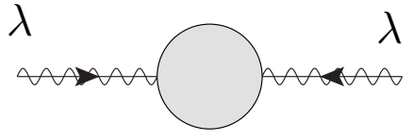
$F.T.\,\langle j_\alpha(x)\bar{j}_{\dot{\alpha}}(y)\rangle$



$F.T.\,\langle J_\mu(x)J_\nu(y)\rangle$



$F.T.\,\langle J(x)J(y)\rangle$



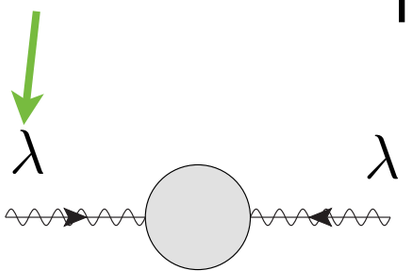
$F.T.\,\langle j_\alpha(x)j_\beta(y)\rangle$

$$\mathcal{L}_{int} = g_{SM}\left(JD + J_\mu A^\mu - j_\alpha\lambda^\alpha - \bar{j}^{\dot{\alpha}}\bar{\lambda}_{\dot{\alpha}}\right)$$

encodes soft masses and scattering cross sections

This is all we know without specifying the hidden sector

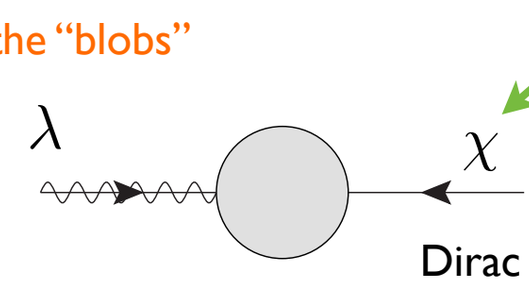
gaugino



Majorana gaugino soft mass

A "model" makes an assumption about the "blobs"

new fermion d.o.f.



Benakli & Goodsell
0811.4409

Dirac soft mass possible

is an sfermion soft mass

perturbative in α_{SM} all orders in hidden sector couplings α_{hidden} SUSY breaking is a non perturbative effect

If the "model" is a just a messenger model then the GGM programme achieves nothing... Just use Giudice & Rattazzi 9801271
S.Martin 9608224

A 10^{?*&!} TeV collider?

$$\sigma(e^+e^- \to \psi, \tilde{\psi}, s)$$
$$\sigma(e^+e^- \to \phi_+, \phi_-, s)$$

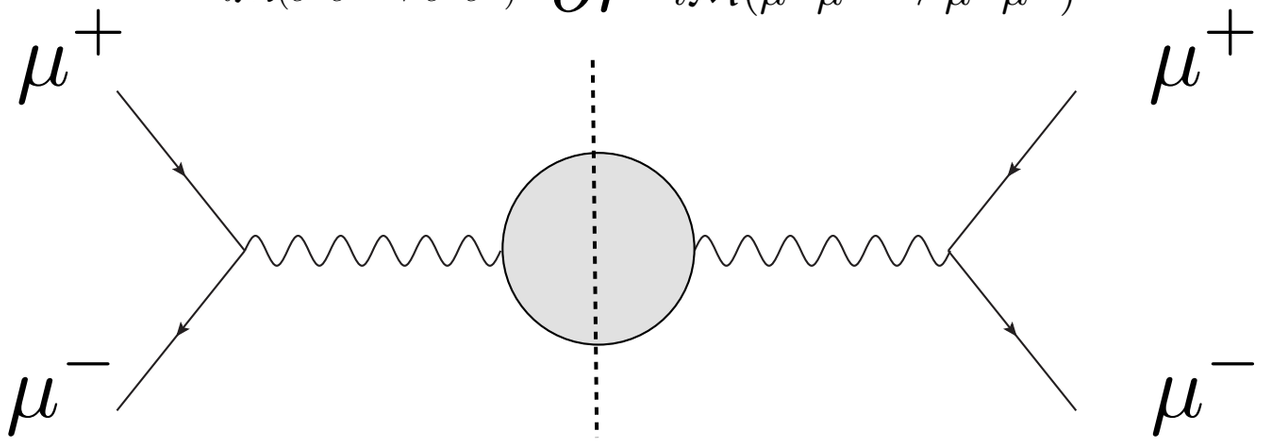
(maybe just 1-10 PeV)

Fortin, Intriligator, Stergiou 1109.4940

cross sections of visible to hidden matter computed for perturbative messenger models.

$$i\mathcal{M}(e^+e^- \to e^+e^-) \quad or \quad i\mathcal{M}(\mu^+\mu^- \to \mu^+\mu^-)$$

Visible sector:
leptons
sleptons
quarks
squarks
....



(Big assumption)

Perturbative
hidden sector:
messenger fields
+ spurion

$$W = X\Phi\tilde{\Phi}$$

$$X = M + \theta^2 F$$

$$\phi_\pm \text{ with } m_\pm^2 = M^2 \pm F$$

$$\psi, \tilde{\psi} \text{ with } M$$

optical theorem

$$i\Pi^{\mu\nu} = e^2 \int d^4x e^{-ip.x} \langle J^\mu(x) J^\nu(0) \rangle$$

$$\sigma(\text{visible} \to \text{hidden}, s) = \frac{(4\pi\alpha)^2}{2s} \text{Disc } \Pi(s)$$

Examples

~~SUSY~~

$$\text{Disc}\tilde{C}_0(s) = \frac{1}{4\pi s}\sqrt{s^2 - 4|X|^2 + 4|F|^2}$$

"In principle" determine GGM correlators from experimental cross sections

$$i(16\pi^2\alpha)^2 \left[\tilde{C}_a(s) - \tilde{C}_a(0)\right] = \sum_{cuts} \frac{s}{\pi} \int_{s_0'}^{\infty} ds' \frac{\sigma_a(s')}{s' - s}$$

SUSY

$$\text{Disc}\tilde{C}_0(s) = \frac{1}{4\pi s}\left(1 - \frac{4M^2}{s}\right)^{1/2}$$

soft masses and cross sections are related McGarrie 1207.4484

BUT we need to get away from perturbative messenger models

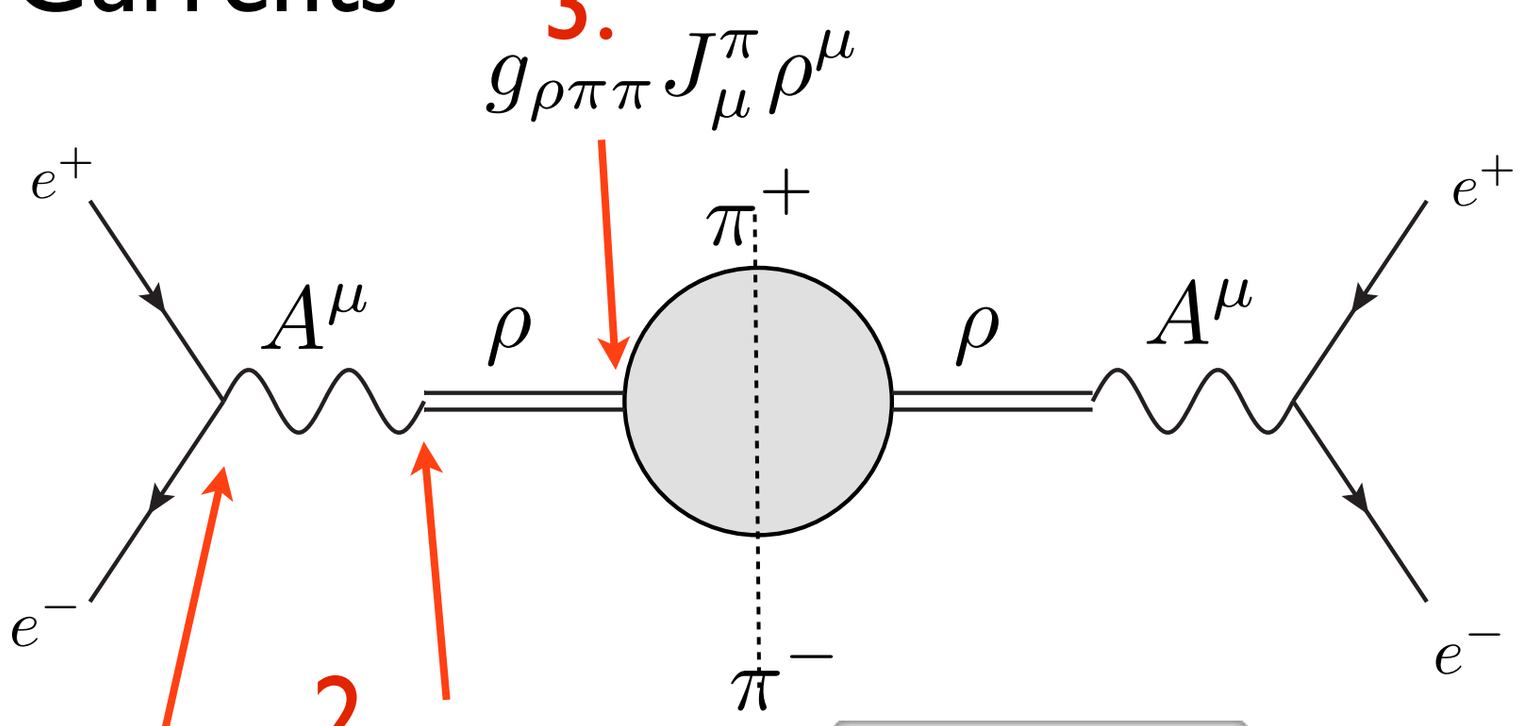
Can we develop intuition with QCD?

Can QCD tell us something about the "blobs" and therefore something about the soft masses?

Pion physics and vector meson dominance $\sigma(e^+e^- \to \pi^+, \pi^-)$

Nambu 1957
Sakurai 1960
Murray Gell-Mann 1961
Kroll, Lee & Zumino 1967
+ many many more

Lesson: 3 Currents



A hidden local symmetry

Completely 4D

$$J^{\rho}_{\mu} = -\frac{m^2_\rho}{g_\rho}\rho_\mu$$

The famous "current field identity"

$$\langle A|g_e J^{em}|B\rangle = \frac{-g_e}{g_\rho}\frac{m^2_\rho}{q^2 - m^2_\rho}\langle A|g_{\rho\pi\pi}J^{\pi}|B\rangle$$

"modified current operator"

A form factor

We learn that

a) Pions couple to rho

b) There is a form factor

Can we build this into GGM? YES

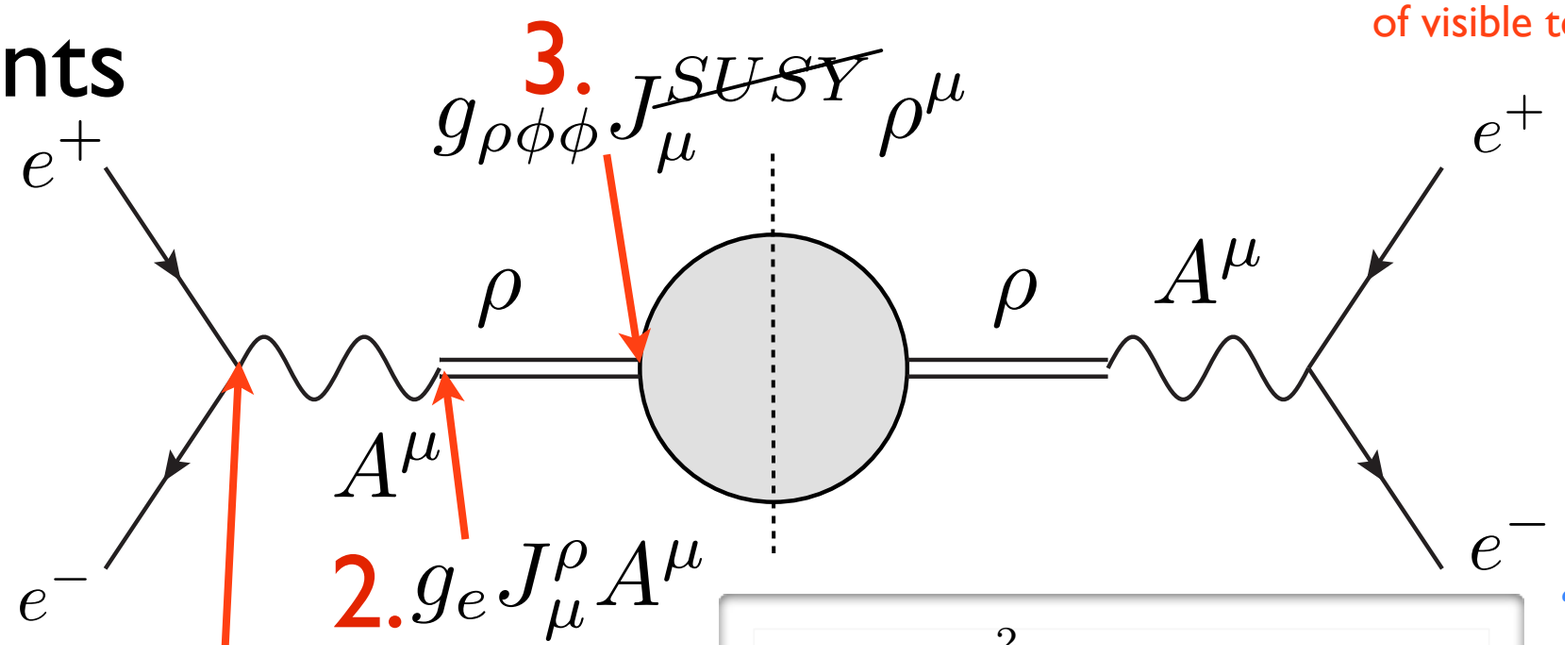
"General Resonance Mediation": McGarrie 1207.4484

Visible to hidden sector messengers

$$\sigma(e^+e^- \to \rho \to \phi^+\phi^-)$$

Intermediate resonances in cross sections of visible to hidden sector

3 Currents



"supercurrent field identity"

McGarrie 1207.4484

$$\mathcal{J}_\rho = -\frac{m_\rho^2}{g_\rho}\rho \quad \text{where} \quad D^2\rho = 0$$

"modified current operator"

A form factor

$$\langle A|g_e J^{em}|B\rangle = \frac{-g_e}{g_\rho}\frac{m_\rho^2}{q^2 - m_\rho^2}\langle A|g_{\rho\phi\phi} J^{\cancel{SUSY}}|B\rangle$$

Completely 4D

In general

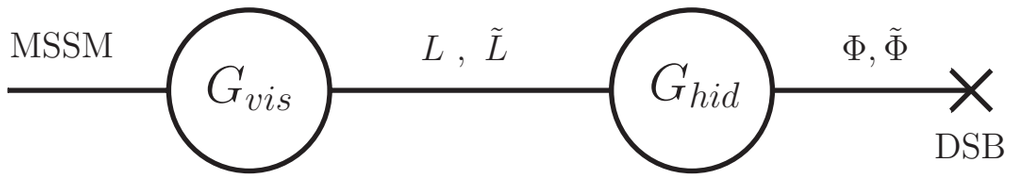
$$\sigma_a(\text{visible} \to \text{hidden}, s) = \frac{(4\pi\alpha)^2}{2s}\int \sigma^2 \frac{\rho(\sigma)}{s - \sigma^2 + i\sigma\Gamma}\int \sigma'^2 \frac{\rho(\sigma)}{s - \sigma'^2 - i\sigma'\Gamma}\text{Disc}\ \tilde{C}'_a(s)$$

We now know all cross sections for visible sector to a perturbative messenger model with intermediate resonances

What does this tell us about SUSY breaking?

$M \geq 10^3\ TeV$

Corresponds to a 2 site quiver model



(Appears also in Seiberg dual models: Green, Katz, Komargodski 1008.2215)

Form factor

$$F(s) = \frac{m_\rho^2}{s + m_\rho^2}$$

"GGM and Deconstruction"
McGarrie 1009.0012 and 1101.5158

Extensions in

Auzzi & Giveon
1009.1714
1011.1664
+ ...

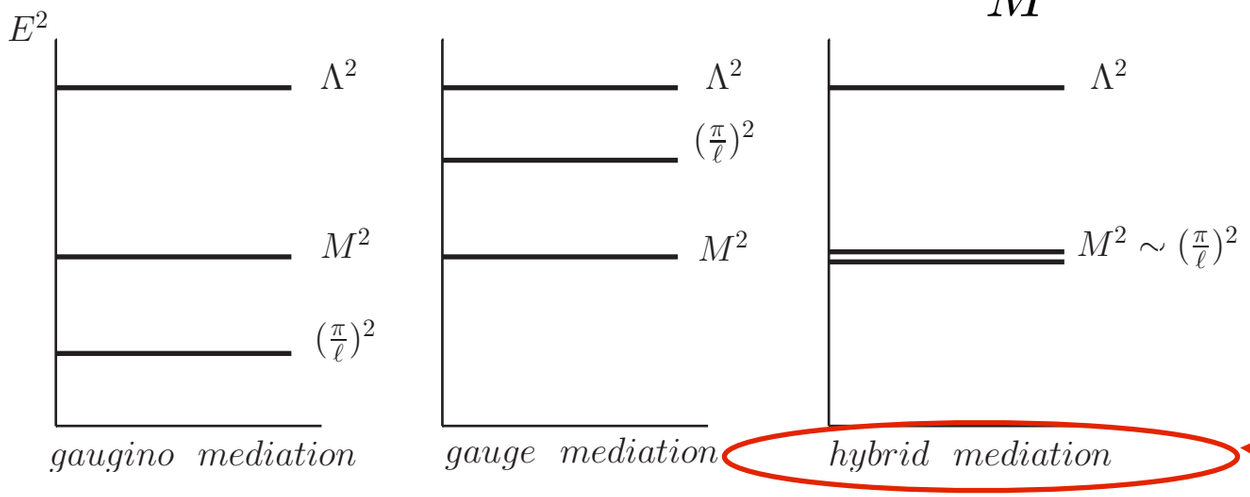
A hidden local symmetry: scattering would measure the magnetic gauge coupling g_m

All soft masses and cross sections can now be computed for a perturbative messenger sector *with intermediate resonances*

a new angle on deconstruction
Csaki, Erlich Grojean, Kribs
0106044
+ ....

3 Regimes

depends on ratio $y = \frac{m_\rho}{M}$



$@M_{SUSY} : m_\lambda^2 \gg m_{\tilde{f}}^2$ $@M_{SUSY} : m_\lambda^2 \sim m_{\tilde{f}}^2$

when $m_\rho \sim M_{SUSY}$

We have a new hybrid regime where

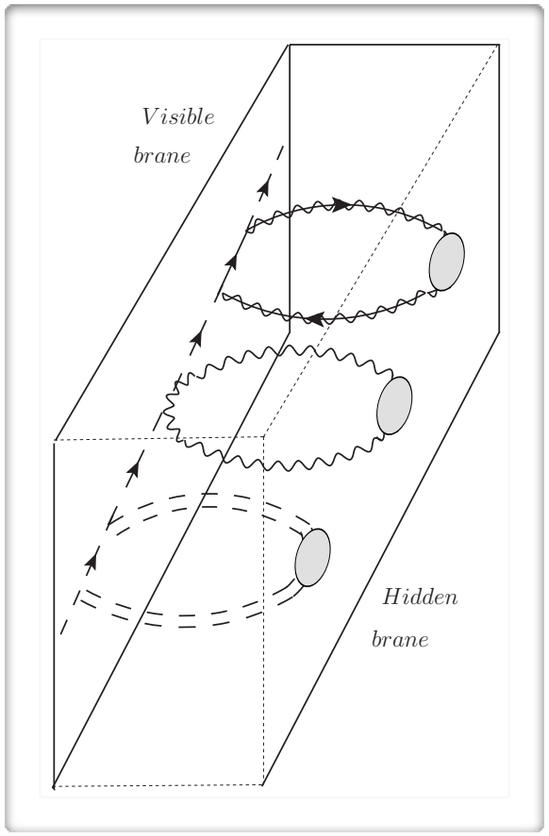
$$@M_{SUSY} : m_\lambda^2 > m_{\tilde{f}}^2$$

in which soft masses are analytically calculable to 2 loops!
and cross sections are now known.

most likely?

Similar to hadronic world: perhaps we should take it more more seriously?

Completely 4D Giveon at al 1208.6263: achieve 126 GeV Higgs and 600 GeV stops with M@ 10^3 TeV with a flavour modification of this quiver



Can this be generalised? YES

Catalogue the form factors from the spectral function

$$\langle B|J^{em}|A\rangle = \int d\sigma^2 \frac{\rho(\sigma)}{s-\sigma^2+i\sigma\Gamma}\langle B|J^{\rho_n}|A\rangle$$

"GGM5D"
Based on the
Mirabelli & Peskin model
9712214

ISS on a brane?

we did it first in here

Perhaps more interestingly,
Can we realise this Holographically??

YES

"Warped General Gauge Mediation"

SUSY broken spontaneously

1009.4696

McGarrie & Daniel C.Thompson

then...

"General Gauge Mediation in 5D"
McGarrie & Rodolfo Russo 1004.3305

(for the soft masses) $ds^2 = e^{-ky}\eta^{\mu\nu}dx_\mu dx_\nu + dy^2$

$$\rho(s) = \sum_m m_n^2(-1)^n\delta(\sigma^2-m_n^2)$$

a natural solution to the hierarchy problem!

ISS at the bottom of a warped throat
soft masses first in here

A flat extra dimension

$$m_n^2 = (\frac{n\pi}{\ell})^2$$

Regge-like mediation

$$m_n^2 = n\mu^2+\mu$$

5d..... but?

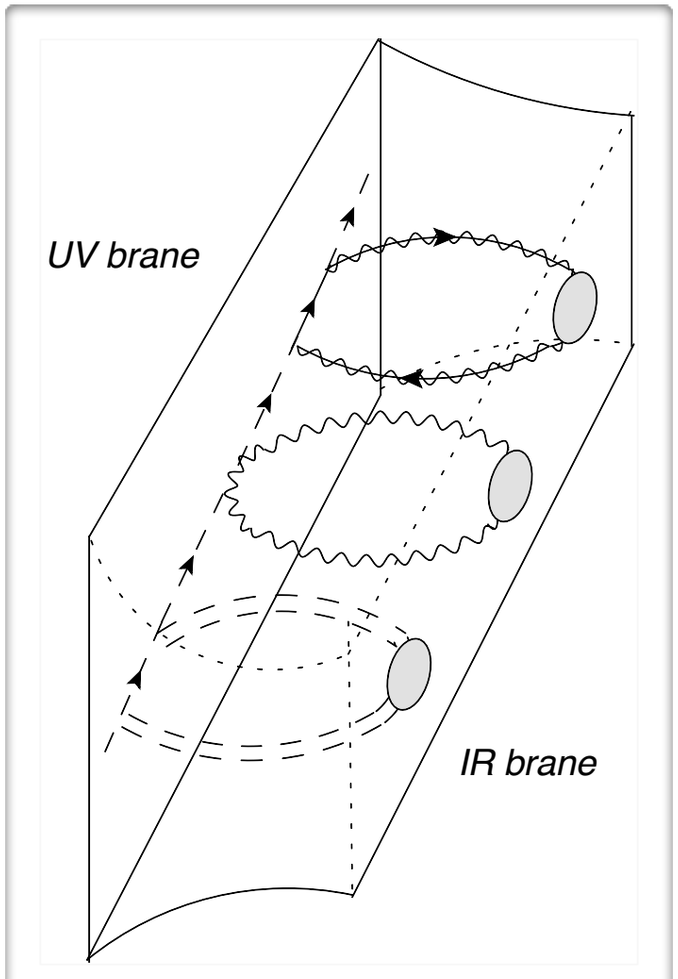
$$M_{SUSY} \sim e^{-k\ell}M_{Planck}$$

"Holography and General Gauge Mediation"

McGarrie (to appear soon)

(for scattering) $ds^2 = \left(\frac{R}{z}\right)^2(\eta^{\mu\nu}dx_\mu dx_\nu + dz^2)$

Completely 4D?



"Holography and General Gauge Mediation"

McGarrie: to appear

"Warped General Gauge Mediation" M.M. Daniel C.Thompson 1009.4696

$AdS/\cancel{SUSY}$

motivated by

AdS/QCD

Son & Stephanov 0304182

Erlich, Katz, Son & Stephanov 0501128

Da Rold & Pomarol 0510268

Gherghetta & Pomarol 0003129

$$ds^2 = \left(\frac{R}{z}\right)^2 (\eta^{\mu\nu} dx_\mu dx_\nu + dz^2) \qquad L_0 < z < L_1$$

3 Currents

1. $g_{SM} \int d^4\theta J_{MSSM} V_{SM}$ standard model currents outside AdS system
2. $g_{SM} \int d^4\theta V_{SM} \mathcal{O}$ on UV boundary
3. $g_5 \int d^4\theta V_{bulk} \mathcal{J}_{\cancel{SUSY}}$ SUSY breaking currents located on an IR brane

The analogue current field identity is the operator field correspondence

$$\frac{R}{g^2_{5d(YM)}} = \frac{N_c}{12\pi^2}$$

standard model gauge fields are sources A_0^μ

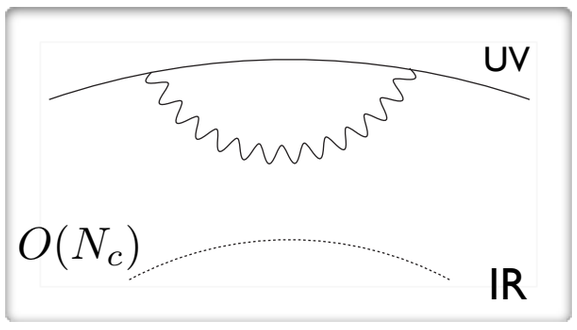
CFT operator correspond to a bulk field $\mathcal{O}(x) \to A_\mu(x,z)$

$$A^\mu(q,z) = A_0^\mu(q) \frac{V(q,z)}{V(q,L_0)}$$ bulk to boundary propagator

$$V(p,z) = pz\left[Y_0(pL_1)J_1(pz) - J_0(pL_1)Y_1(pz)\right]$$

UV boundary correlators give supersymmetric effective action: encodes the bulk propagator

$$\Pi(q^2) = \frac{1}{q}\left(\frac{R}{z}\frac{\partial_z V(q,z)}{V(q,L_0)}\right)_{z=L_0} \qquad \int d^4x e^{ip.x} \langle \mathcal{O}_\mu(x)\mathcal{O}_\nu(0)\rangle = \Pi(p^2)P^{\mu\nu}$$



A Witten diagram

$\int d^4x e^{ip.x} \langle \mathcal{J}_\mu(x)\mathcal{J}_\nu(0)\rangle = \tilde{C}_1(p^2)P^{\mu\nu}$ IR localised correlators encode supersymmetry breaking

SUSY breaking couples to the CFT states, NOT the sources directly

$$\overset{5d}{A_\mu J^\mu} = \int dz K(p,z) A_\mu^0 J^\mu = A_\mu^0 J^\mu \overset{4d}{\Lambda}(p)$$

An effective vertex generated by bulk to boundary propagator

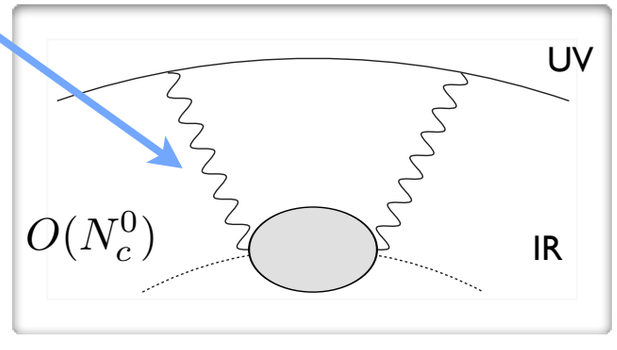
$$A_\mu^0 \Lambda(p) \tilde{C}(p^2/M^2) P^{\mu\nu} \Lambda(p)\ A_\nu^0$$

Soft masses and cross sections arise from strings of correlators

$$m^2_{\tilde{f}} \sim \langle \mathcal{O}\mathcal{O}'\rangle \langle \mathcal{J}\mathcal{J}\rangle \langle \mathcal{O}\mathcal{O}'\rangle$$

Key point: Calculable!

$$\sigma_a(\text{visible} \to \text{hidden}, s) \sim \frac{(4\pi\alpha)^2}{2s} \langle \mathcal{O}\mathcal{O}'\rangle \langle \mathcal{O}\mathcal{O}'\rangle \,\text{Disc}\ \langle \mathcal{J}\mathcal{J}\rangle (s)$$



Essentially the UV to IR Green's function is the form factor

Ignore $O(1/N_c)$ corrections

Moritz McGarrie

Thanks for listening

Outlook

"Perhaps these "5D" models should be more mainstream?"

Intermediate resonances suppress sfermion masses (@M_SUSY)

Gaugino mediation or Hybrid mediation?

4D* and calculable

Strong overlaps with hadronic world

Strong overlap with AdS/QCD

Forget simple messenger models

(we only use them because they are easy to compute)

Extensions:

Relate the form factors to OPE's

What can we learn about the UV of the theory from the weakly coupled dual?

AdS/QCD

Seiberg duality

Quark -Hadron duality