16 Apr.

David Marsh. SUGRA ~~for~~ by PHENO

Motivation: susy. strings

- cosmo: $\underbrace{\Lambda, \text{ inflation, reheating, baryogen.}}_{\text{in fact, all rel to } \cancel{\text{susy}}}$
- PHENO: susy ← ~~today~~
- GAUGE/GRAVITY:

~~SUSY~~ in SUGRA

$$Q = \tilde{q} + \sqrt{2}\,\theta\psi + F_q\theta^2$$

relevant ops

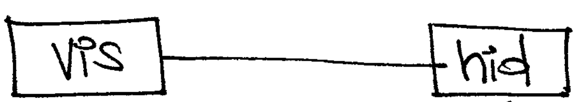
$$\mathcal{L}_{SOFT} = \tfrac{1}{2} m_{soft} |\tilde{q}|^2 \qquad \text{SOFT MASS}$$
$$+ \tfrac{1}{2} B\mu\, q^2 + c.c. \qquad \text{"HOLOMORPHIC" TERMS}$$
$$+ \tfrac{1}{3!} A_{ijk}\, \tilde{q}^i \tilde{q}^j \tilde{q}^k + \cdots + c.c.$$
$$+ M_\lambda \lambda\lambda + c.c. \qquad \text{GAUGINO MASSES}$$

low e pheno det by these
GEN. of THESE FROM UV THY IS
STORY of ~~SUSY~~

~~SUSY~~ SCENARIOS: HOW TO GEN.

1. NON-REN. OPS ⇝ GRAV MEDIATION
2. LOOP INTERACTIONS ⇝ GAUGE MEDIATION

} mix: anomaly



~~susy~~ (1 or 2)

1. GRAVITY MEDIATION

CONSIDER FUNDAMENTAL THY w/

$$K = \frac{1}{M_{Pl}^2} X^\dagger X Q^\dagger Q$$

$$X = x + \theta^2 F_X$$

$$\mathcal{L} = \int d^4\theta \, \frac{1}{M_P^2} X^\dagger X Q^\dagger Q$$
$$= \frac{1}{M_P^2} F_X^2 \, \tilde{q}^* \tilde{q}$$

& similar for B term
A & m_λ from similar game in superpot.

eg if $F_X \sim (10^{10}\ \text{GeV})^2$
then acceptable soft masses

How to generate this in SUGRA?

$$\mathcal{L} = c_{ij} \int d^4\theta \, \frac{1}{M_P^2} X^\dagger X \underbrace{Q_i^\dagger Q_j}_{\text{flavors}}$$

mass matrix

FCNC $\Rightarrow$ c_{ij} wants to be diagonal
BUT "GRAVITY DOESN'T RESPECT GLOBAL SYM" so
NO FLAVOR GAMES TO PLAY.

Conformal compensator formalism

motiv: promote on-shell action to offshell
idea: start w/ SUPERCONFORMAL SUGRA
& break to non-conformal SUGRA

USED by Randall & Sundrum - OUT OF THIS WORLD SUSY

$$\frac{1}{\sqrt{-g}}\mathcal{L} = \int d^4\theta\, \Phi^\dagger \Phi\, f(Q^\dagger, Q) + \int d^2\theta\, \left(\Phi^3 W(Q) + \tau W_\alpha W^\alpha\right) - \frac{1}{6} R g^\dagger g + \text{fermions}$$

$[f] = 2$

$R[\phi] = 0$

$f = -3M_{pl}^2 e^{-k/3m_{pl}^2}$

Φ is CONFORMAL comp. : (ϕ, ψ, F_ϕ)

F_Φ WILL BE AN AUX COMP of GRAVITY MULTIPLET

$$\uparrow$$

$$(e^a_\mu,\ \psi_{a\mu},\ P_\mu)$$

$\langle\phi\rangle$ BREAKS CONFORMAL SYM

(F_ϕ, P_μ) IS AUX DOF OF GRAV MULTIPLET

$\langle F_\phi\rangle$ $\rightarrow$ VEV IS THE SOURCE of GRAVITY MEDIATION

STANDARD GAUGE CHOICE : $\Phi = 1 + \theta^2 F_\phi$

note: $[\Phi] = 0$, convention

$R[\Phi] = 2/3$

[Randall & Sundrum: out of this world susy] ↗ 'anomaly mediation'

LET'S SEE WHAT KIND of SOFT MASSES WE GET

on-shell formalism

$$\left(m^2_{\text{soft}}\right)_{a\bar{b}} = \underbrace{\left(F^2 - 2m_{3/2}^2\right)}_{m_{3/2}^2} \underset{\propto \mathbb{1} \text{ after canonical norm.}}{K_{a\bar{b}}} - \underline{R_{a\bar{b}c\bar{d}} F^c F^{\bar{d}}}$$

$F^2 = 3m_{3/2}^2$ for $\Lambda \sim 0$

danger: will give off-diag soft terms [even there in off shell formalism]

⇒ need extra ingredients to suppress FCNC

$\boxed{\text{RS}}$: suppose we have $W = W_{\text{vis}} + W_{\text{hid}}$

$W_{\text{vis}}(Q)$ $V_{\text{vis}}(x)$

(SEPARABLE!)

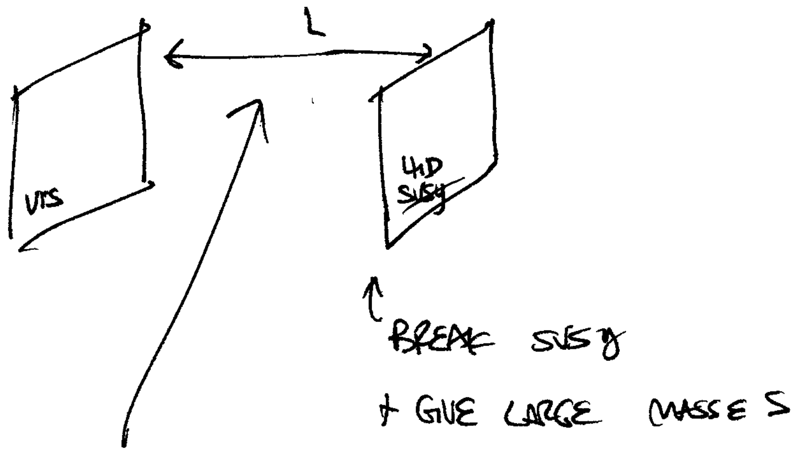
ALSO: $f = f_{\text{vis}} + f_{\text{hid}}$

$\tau = \tau_{\text{vis}} + \tau_{\text{hid}}$

then in $\frac{1}{f_g}\mathcal{L}$, VIS & 4D SECTORS DECOUPLE

$\Rightarrow$ <u>SEQUESTERING</u>.

<u>XD picture</u>



$\Rightarrow$ HAS TO OCCUR THROUGH F_ϕ (gravity mediation)

<u>BUT</u>: $\exists$ KK MODES $m \sim 1/L$

$G_F^{kk}(L)$ $\Leftarrow$ GREEN'S FUNK FOR KK MODE

$\hookrightarrow \; = \; e^{-M_{kk}L}$ & not small!

$M_{kk} \sim 1/L$

PROBLEM!

hand wave: embed into ~~susy~~ strings & ignore string-scale-ish KK modes.

$$\frac{1}{\sqrt{g}}\mathcal{L} = \int d^4\theta\, \Phi^\dagger\Phi\, f(Q^\dagger Q) + \int d^2\theta\, (\Phi^3 W + \tau W^2) - \frac{1}{6}\tilde{g}^\dagger\tilde{g} + \cdots$$

Soft masses explicitly

ASSUME WE HAVE SEQUESTERING

& THAT WE'VE INTEGRATED OUT HID SEC.

$$(F_\phi \neq 0)$$

$$\frac{1}{\sqrt{g}}\mathcal{L} = \overset{①}{|F_\phi|^2 f(q,\bar{q})} + \overset{④}{F_\phi \bar{F}_{\bar{q}}\, \bar{\partial}_{\bar{q}} f} + \text{c.c.}$$

$$③\ + |F_q|^2 \partial_q \bar{\partial}_{\bar{q}} f + \text{c.c.}$$

$$+ \underset{②}{3F_\phi W} + F_q \partial_q W + \text{c.c.}$$

solve for F_q:

$$F_q = \left(\frac{\bar{\partial}\bar{W} + \bar{\partial} f\, F_\phi}{\partial\bar{\partial} f}\right) \longrightarrow \text{plug back in}$$

bottom line of sequestering

$$V_{VIS} = \underset{③+④}{\frac{|\partial W + \partial f\, \bar{F}_\phi|^2}{\partial\bar{\partial} f}} - \underset{②}{6\,\mathrm{Re}(W F_\phi)} - \underset{①}{f_{VIS} |F_\phi|^2}$$

RS: "obviously scalar masses cancel"
but this isn't obvious or true!

Assumed

$$f = \phi\phi^* + \text{(Planck suppressed)}$$

$$W = \tfrac{1}{2}\mu\phi^2 + \tfrac{\lambda}{6}\phi^3$$

$$V_{vis} = \begin{cases} |\mu\phi + \tfrac{1}{2}\lambda\phi^2 + \underline{\underline{\phi^* F_\phi}}|^2 \\ - 6\,\mathrm{Re}\left(\left(\tfrac{1}{2}\phi^2 + \tfrac{1}{6}\phi^3\right)F_\phi\right) \\ - \underline{\underline{\phi\phi^*|F_\phi|^2}} \end{cases}$$

underlined terms cancel (RS obs.)

but: wiggly terms also contribute
+ supersym masses from μ term.

$$= \underbrace{|\mu^2||\phi|^2 + (\mu F_\phi \phi^2 + c.c.) - 3\mathrm{Re}(\mu\phi^2 F_\phi)}_{\text{SCALING SOFT MASSES}}$$

SUSY

$\hookrightarrow$ but these terms don't exist for SM fermions

POINT: still no general $\exists$ masses!

So where do the soft masses come from?

Anomaly Mediation

Φ couples to all things w/ mass dim.
& couples equally

so: introducing a ~~cutoff~~ Λ_{UV},
it really comes w/ $(\Lambda_{UV}\Phi)$

Λ APPEARS IN LOOPS
$\rightarrow$ Φ APPEARS IN LOOPS
$\rightarrow$ F_ϕ ———

so: we've argued that the tree-level terms don't show up for our models of interest

so these loopy terms are now the leading terms to soft masses.

breaking conf

why?

$$m_\lambda = \frac{\beta(g)}{2g} F_\phi = b_0 \frac{g^2}{16\pi^2} F_\phi$$

$$m^2 = \pm \frac{g^4}{(16\pi^2)^2} |F_\phi|^2$$

loop factors (flavor indep)
& come w/ $F_\phi \sim M_{Pl}$

(Anomaly? → { Konishi
Super Weyl

-- UP TO INTERPRETATION.)

left tacit

still other contributions @ loop level
made some assumptions s.t. these
flavor universal terms would dominate

(analogous to tree level terms)

eg. $\Delta m^2 = F^i \partial_i \ln(\det Z) + F^i \partial_i K$] bagger + poppitz

assump. about vevs in hidden sector, Kw..

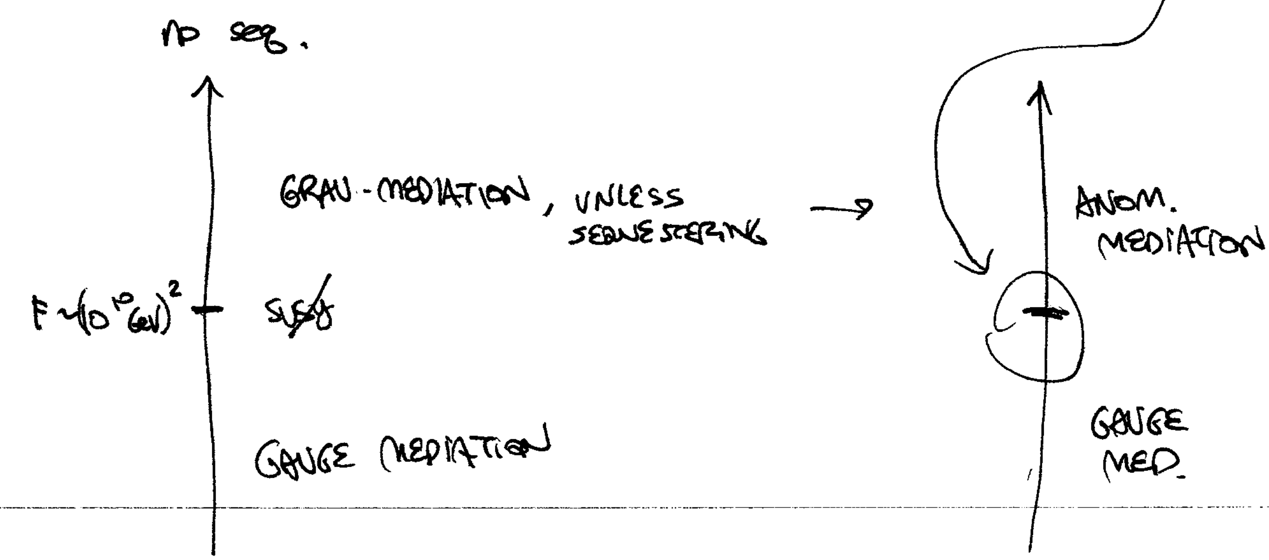
note: m^2 has $\pm$

IR free → −

SLEPTONS → tachyonic masses!

HARD TO fix w/M ANOMALY MED.
so try to balance these contributions
w/ ~~gravity~~ gauge mediation contributions.

how to get rid of additional KK stuff
↳ WARPING
↳ conformal SEQUESTERING



eg: Anom med gives M_x, A terms, ...
that GAUGE MED DOES NOT.