Supersymmetry Breaking

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What is the New Physics at TeV?

→ We don't know

Is there New Physics at TeV?

→ We don't know

Possible (observational) hints

- Existence of the Dark Matter
- Gauge Coupling Unification

Weak Scale Supersymmetry

May also be responsible for weak-Planck hierarchy

… theory of radiative EWSB

→ Need an experimental confirmation … LHC!

Outline

- Weak scale supersymmetry
  - Motivation
  - (A little bit of) history
- Supersymmetry breaking
  - Tree-level supersymmetry breaking
  - Dynamical supersymmetry breaking
- Mediation mechanism
  - “Gravity’’ mediation (high scale mediation)
  - Gauge mediation (low scale mediation)
- Phenomenology
  - Superparticle spectrum and collider signatures
  - Little hierarchy problem, cosmology, …

Useful ref: S. P. Martin, “A Supersymmetry Primer,” hep-ph/9709356

Supersymmetry (SUSY)

Extension of spacetime symmetry: $x^\mu \to x^\mu, \theta^\alpha$

$\{P^\mu, J^{\mu\nu}, Q^\alpha, \bar{Q}_{\dot{\alpha}}\}$: $Q_\alpha\,|\text{boson}\rangle \to |\text{fermion}\rangle$

can naturally arise in string theory

… Largest spacetime symmetry

consistent with chiral structure of the SM

May be realized at observable energies

"SUSY SM" (SSM)

q (quarks) $\leftrightarrow$ $\tilde{q}$ (squarks)

l (leptons) $\leftrightarrow$ $\tilde{l}$ (sleptons)

A_μ (gauge) $\leftrightarrow$ λ (gauginos)

SUSY must be a broken symmetry

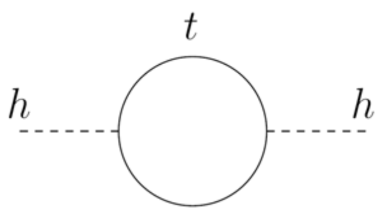
Early attempts Fayet, … (late '70s)

The 1st SUSY revolution

Witten ('81); Dimopoulos, Georgi ('81); Sakai ('81); Dine, Fischler, Srednicki ('81); Dimopoulos, Raby ('81); Chamseddine, Arnowitt, Nath ('82); Barbieri, Ferrara, Savoy ('82); …

Gauge hierarchy problem

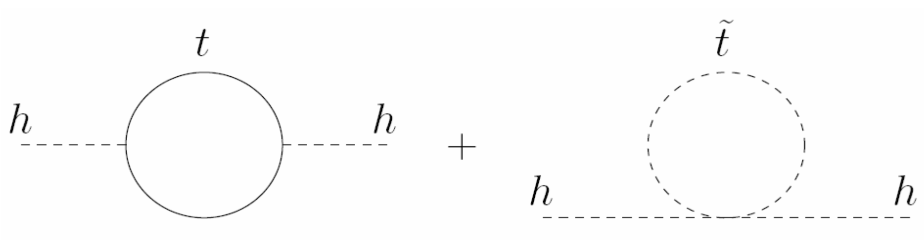
$V_{Higgs} = m_h^2 |h|^2 + \lambda |h|^4/4$



$$\delta m_h^2 \approx -\frac{y_t^2}{16\pi^2}\Lambda^2$$

Electroweak scale is unstable in the SM

Weak scale SUSY stabilizes it



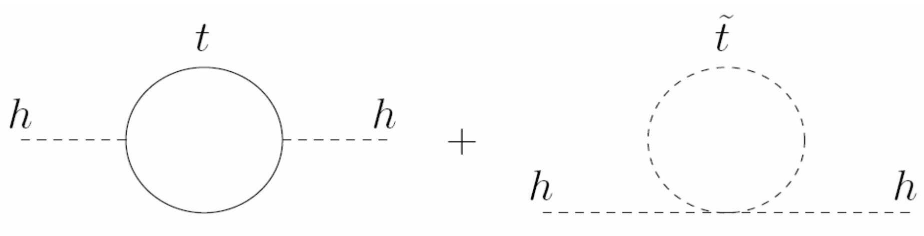
$\delta m_h^2 \sim m_{SUSY}^2 \ln\Lambda$

The scale of ~~SUSY~~ can be naturally small

$$m_{SUSY} \sim M_{Pl}\, e^{-\frac{8\pi^2}{|b| g^2}}$$

… dynamical SUSY breaking (DSB)

Electroweak symmetry can be broken radiatively



Ibanez, Ross ('82); Alvarez-Gaume, Polchinski, Wise ('82); Inoue, Kakuto, Komatsu, Takeshita ('83); …

$$\delta m_h^2 \approx -\frac{3y_t^2}{4\pi^2} m_{\tilde{t}}^2 \ln \frac{\Lambda}{m_{\tilde{t}}}$$

negative sign

… $m_h^2 < 0$ while $m_{\tilde{q}}^2$, $m_{\tilde{l}}^2 > 0$

… requires large top quark mass (y_t)

Minimal supersymmetric standard model (MSSM)

Vector multiplet $\{A_\mu, \lambda\}$: $V_{SU(3)_C}$, $V_{SU(2)_L}$, $V_{U(1)_Y}$

Chiral multiplet $\{\phi, \psi\}$: 3 x (Q, U, D, L, E), H_u, H_d

$W = H_u H_d + QUH_u + QDH_d + LEH_d$

+ ~~LH_u~~ + ~~QLD~~ + ~~UDD~~ + ~~LLE~~

R parity

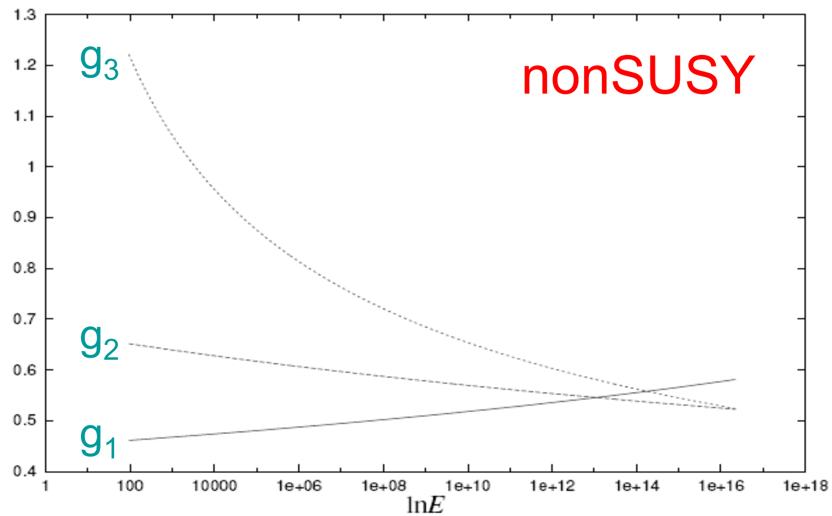
- Superparticles always pair produced
- Lightest superparticle (LSP) stable

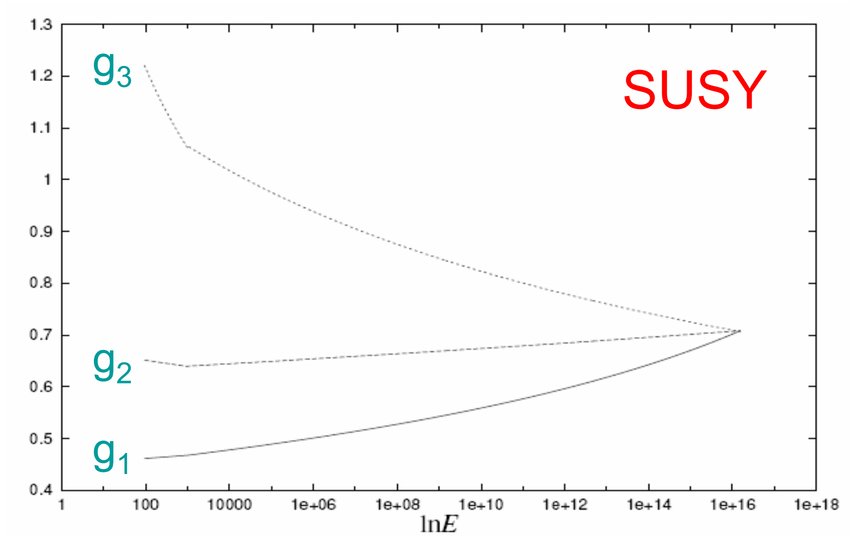
… Dark matter candidate

Goldberg ('83); Ellis, Hagelin, Nanopoulos, Olive, Srednicki ('84); …

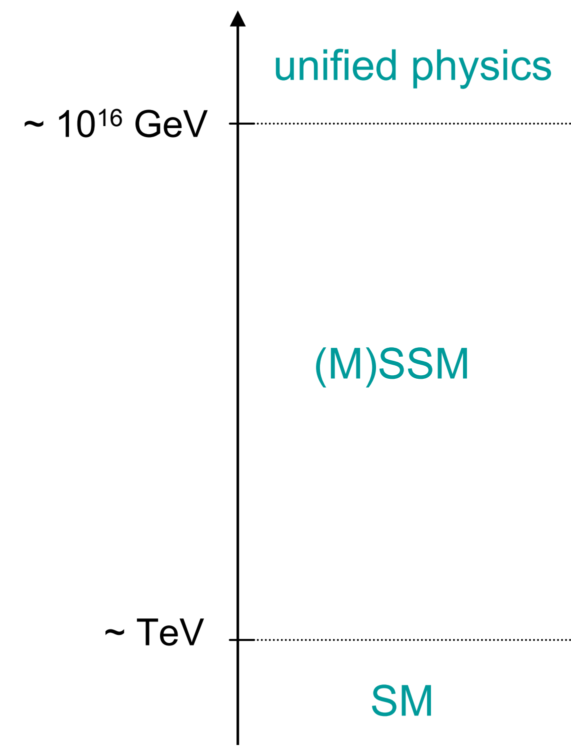
The 2nd SUSY revolution … early 90's

LEP data





Clear picture



M_{unif} ~ 10^{16} GeV

also, heavy top (Tevatron)

Issues

How to break SUSY (dynamically)?

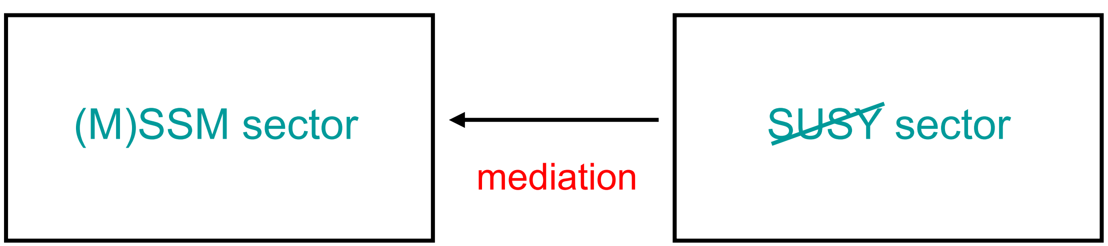
– It did not seem easy to break SUSY dynamically

How to “mediate” ~~SUSY~~ to the SSM sector?

– ~~SUSY~~ in the SSM sector leads to too light superparticles

$\mathrm{Tr}(-)^F m^2 = 0 \quad \rightarrow$ some $\tilde{q} < q$

~~SUSY~~ must occur in some other sector
and then “mediated” to the SSM sector



After integrating out the ~~SUSY~~ sector, the (M)SSM sector appears as softly broken SUSY theory

$$W = \mu H_u H_d + y_u QUH_u + y_d QDH_d + y_e LEH_d$$

μ parameter ~ $O(m_{weak})$

Yukawa couplings

$$\mathcal{L}_{soft} = M_a \lambda^a \lambda^a + (m_{\tilde{q}}^2 \tilde{q}\tilde{q} + m_{\tilde{l}}^2 \tilde{l}\tilde{l} + \ldots) + B\mu\, h_u h_d + (a_u \tilde{q}\tilde{u} h_u + \ldots)$$

Gaugino masses

Scalar masses

$B\mu$ parameter

Scalar trilinear

… Soft ~~SUSY~~ parameters determine phenomenology

… Scale of fundamental ~~SUSY~~, *F*, unknown

$$m_{SUSY} \sim \frac{F}{M_{mess}} \sim m_{weak}$$

Scale of mediation: messenger mass

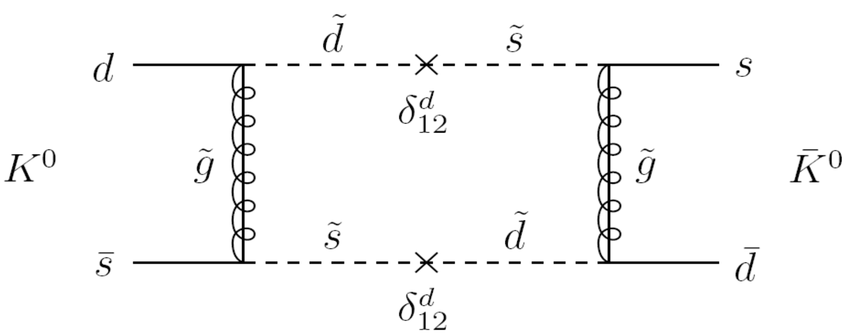
… affect gravitino phenomenology

$$m_{3/2} \sim \frac{F}{M_{Pl}}$$

Most of the (M)SSM parameter region is excluded

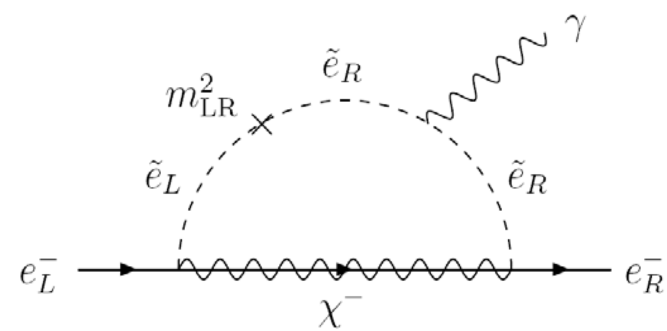
$$m_{\rm SUSY}^2 \begin{pmatrix} \tilde{d} & \tilde{s} & \tilde{b} \end{pmatrix}^* \begin{pmatrix} 1 & \delta_{12}^d & \delta_{13}^d \\ \delta_{21}^d & 1 & \delta_{23}^d \\ \delta_{31}^d & \delta_{32}^d & 1 \end{pmatrix} \begin{pmatrix} \tilde{d} \\ \tilde{s} \\ \tilde{b} \end{pmatrix}$$

~~Flavor~~: K-$\bar{K}$, $\mu \rightarrow e\gamma$, …



$$\delta_{12}^d \lesssim 0.001 \frac{m_{\rm SUSY}}{500 \text{ GeV}}$$

~~CP~~: EDM for e^-, n, Hg, …



$m_{\rm SUSY} \gtrsim 1$ TeV or phase $\lesssim 10^{-2}$

… made even worse after *B* physics data

Special structure needed

→ Hint for mediation (and ~~SUSY~~) mechanism

Flavor universality

$$(m_{\tilde{q}}^2)_{ij} = m_{\tilde{q}}^2\, \mathbf{1},\ \ (m_{\tilde{u}}^2)_{ij} = m_{\tilde{u}}^2\, \mathbf{1},\ \ (m_{\tilde{d}}^2)_{ij} = m_{\tilde{d}}^2\, \mathbf{1},\ \ldots$$

$$(a_u)_{ij} = a_u\,(y_u)_{ij},\ \ (a_d)_{ij} = a_d\,(y_d)_{ij},\ \ldots$$

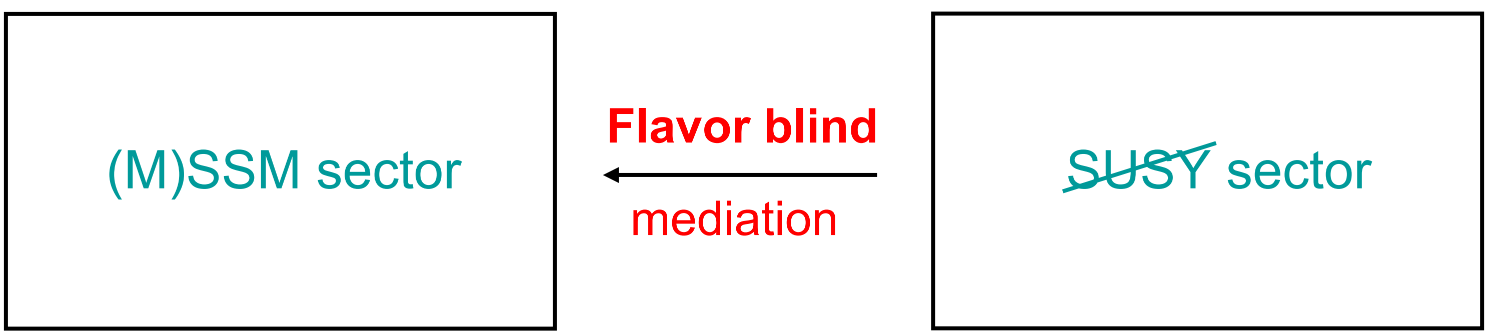
CP conservation

In the field basis where M_2 and $B\mu$ are real,

$$\arg(M_{1,3}),\ \ \arg(\mu),\ \ \arg(A_{u,d,e}) \ = \ 0 \text{ or } \pi$$

can always take this basis

Consistent picture:

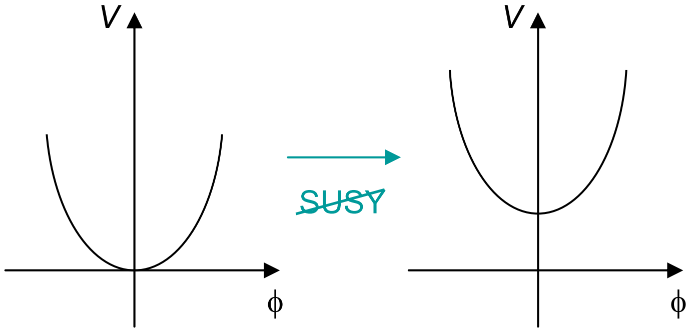


Supersymmetry Breaking

Order parameters

SUSY algebra: $\{Q_\alpha, \bar{Q}_{\dot{\alpha}}\} \sim P^\mu$

$Q_\alpha |0\rangle \neq 0 \leftrightarrow \langle 0|H|0\rangle \neq 0$



Scalar potential in SUSY theories

$$V = \sum_\Phi |F_\Phi|^2 + \frac{1}{2}\sum_a (D^a)^2$$

$$F_\Phi = -\frac{\partial W^*}{\partial \Phi^*}, \quad D^a = -g\sum_\phi \phi^* T^a \phi$$

~~SUSY~~ $\leftrightarrow$ $V > 0$ $\leftrightarrow$ $F_\Phi \neq 0$ … F-type ~~SUSY~~

$D^a \neq 0$ … D-type ~~SUSY~~

This is for global SUSY, but the situation is similar for local SUSY (supergravity)

Fayet-Iliopoulos model (*D*-type ~~SUSY~~)

For U(1) gauge theory,

$$D = \xi - g \sum_{\phi} q_{\phi} |\phi|^2$$

This term (Fayet-Iliopoulos term) is allowed

→ can lead to ~~SUSY~~

e.g. massive SUSY QED

$$V = \sum_{\phi} |M_{\phi}|^2 |\phi|^2 + \frac{1}{2} \left(\xi - g \sum_{\phi} q_{\phi} |\phi|^2\right)^2 \xrightarrow[|m|^2 > g q_{\phi} \xi]{} \begin{array}{l} F_{\Phi} = -M_{\phi} \phi^* = 0 \\ D = \xi \neq 0 \end{array}$$

SUSY mass

Fayet-Iliopoulos term is not allowed in supergravity (SUGRA)

(exception: pseudo-anomalous U(1), gauged $U(1)_R$)

F-type ~~SUSY~~

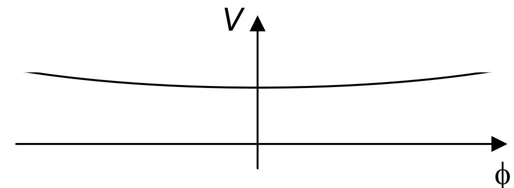
SUSY nonrenormalization theorem: Grisaru, Siegel, Rocek ('79)

W is not renormalized at all orders in perturbation theory

… *F*-type ~~SUSY~~ occurs only at tree or nonperturbative level

Polonyi model

$$W = \Lambda^2 \Phi$$



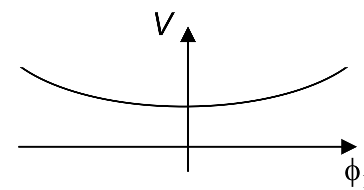
$F_\Phi = -\Lambda^2 \neq 0$: ~~SUSY~~

$$V = |F_\Phi|^2 = \Lambda^4 \xrightarrow{\text{Planck-suppressed corrections}} V = \left(1 + \frac{|\phi|^2}{M_{Pl}^2}\right)\Lambda^4$$

very light field (Polonyi field)

O'Raifeartaigh model

$$W = -\Lambda^2 \Phi_1 + m\Phi_2\Phi_3 + \frac{y}{2}\Phi_1\Phi_3^2$$



$$F_{\Phi_1} = \Lambda^2 - \frac{y}{2}\phi_3^{*2}, \quad F_{\Phi_2} = -m\phi_3^*, \quad F_{\Phi_3} = -m\phi_2^* - y\phi_1^*\phi_3^*$$

$\xrightarrow{m^2 > y\Lambda^2}$ $\phi_2 = \phi_3 = 0$, ϕ_1: undetermined ← flat direction … "lifted'' by radiative corrections

$F_{\Phi_1} = \Lambda^2$, $F_{\Phi_2} = F_{\Phi_3} = 0$ ← ~~SUSY~~

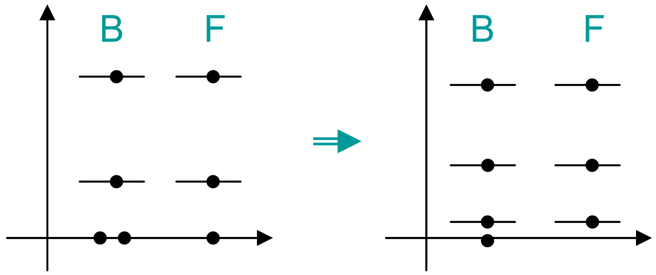
Potentially realistic, but scales "by hand''

(could be string theory origin)

Dynamical SUSY Breaking

Witten index

$\mathrm{Tr}(-)^F$



… topological quantity

(unchanged under continuous deformations of the theory)

→ provides strong constraints on theories with DSB

$\mathrm{Tr}(-)^F$ of the theory must be zero for DSB to occur

$\mathrm{Tr}(-)^F$ is nonzero for pure SUSY Yang-Mills theory Veneziano, Yankielowicz ('82)

→ vector-like theories (apparently) do not break SUSY

DSB occurs (only) in chiral gauge theories Affleck, Dine, Seiberg ('84-'85); …

Incalculable models: *e.g.* SU(5) with **5*** + **10**

Calculable models: *e.g.* "3-2" model

The need of chiral structure adds significant complication in searching theories with DSB

3-2 model

SU(3) x SU(2) SUSY gauge theory

$Q(\mathbf{3},\mathbf{2})$, $U(\mathbf{3^*},\mathbf{1})$, $D(\mathbf{3^*},\mathbf{1})$, $L(\mathbf{1},\mathbf{2})$

$$W = \lambda QDL \;\longrightarrow\; W = \lambda QDL + \frac{\Lambda_3^{\,7}}{(QU)(QD)}$$ … break SUSY

nonperturbatively generated term

The existence of $U(1)_R$

$Q(-1)$, $U(0)$, $D(0)$, $L(3)$ *c.f.* Nelson-Seiberg "theorem" ('94)

DSB can also occur in vector-like theories

Izawa, Yanagida ('96); Intriligator, Thomas ('96)

SU(2) SUSY gauge theory

$4 \times Q(\mathbf{2})$, $6 \times Z(\mathbf{1})$

$$W = \lambda QQZ \;\longrightarrow\; W = \lambda QQZ + X((QQ)(QQ) - \Lambda^4)$$ … break SUSY

dynamical field (X); nonperturbatively generated term

Still, theories with DSB look (very) special

Meta-stable ~~SUSY~~

We may not live in a global minimum of the potential

c.f. Cosmological constant problem, the multiverse, string landscape

… tremendously simplifies the story   No need of $\mathrm{Tr}(-)^F = 0$, $U(1)_R$, …

e.g.

Dynamically generate a mass in an O'Raifeataugh model

Massive QCD with $N_c < N_f < (3/2)N_c$

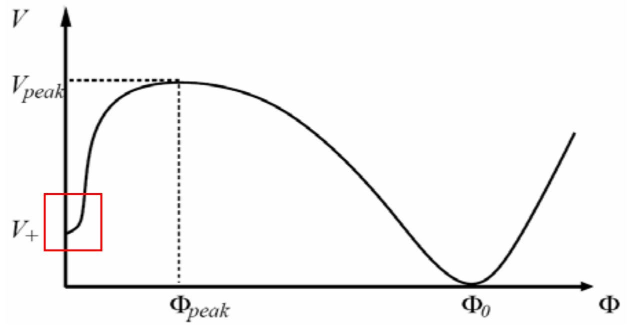
Intriligator, Seiberg, Shih ('06)

$SU(N_c)$ SUSY gauge theory with $N_f(Q + \bar{Q})$

$$W = mQ\bar{Q} \longrightarrow W = mQ\bar{Q} + W_{\mathrm{dyn}}$$

can be of dynamical origin

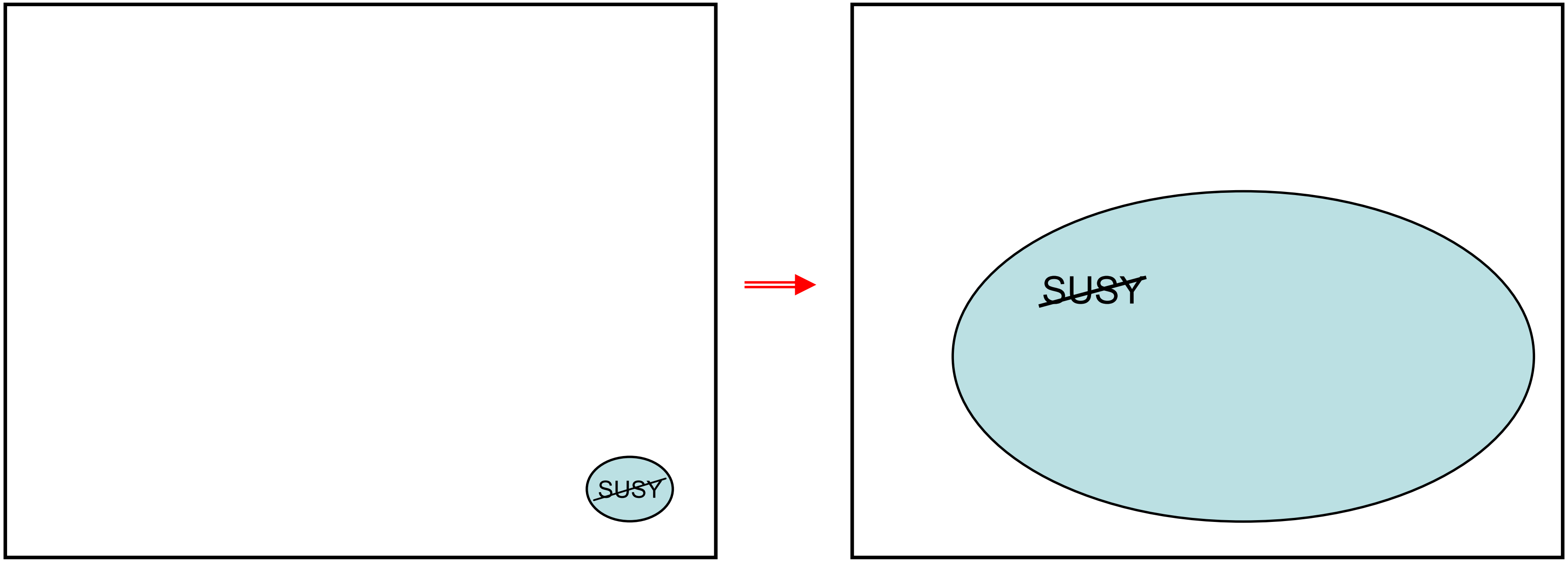
nonperturbative term



The theory reduces to an O'Raifeataigh model locally around the origin in field space

Many simple theories exhibit this type of behavior

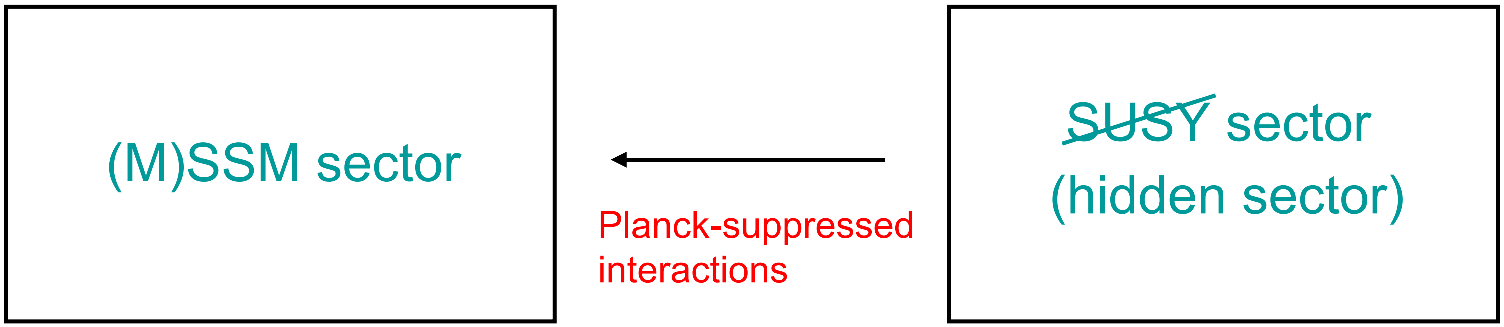
DSB as a generic phenomenon
in the landscape of possible SUSY theories



True meaning of this observation
is not completely clear (*e.g.* anthropic, …),
but it is certainly comfortable

Mediation of ~~SUSY~~

"Gravity" mediation



Suppose ~~SUSY~~ by some singlet X

Chamseddine, Arnowitt, Nath ('82); Barbieri, Ferrara, Savoy ('82); Hall, Lykken, Weinberg ('84); …

$$F_X = -\frac{\partial W^*}{\partial X^*} \neq 0$$

Planck-suppressed (nonrenormalizable) interactions $M_* \sim M_{Pl}$

$$\mathcal{L} = \left[\frac{X}{M_*}\mathcal{W}^\alpha \mathcal{W}_\alpha\right]_{\theta^2} + \left[\frac{X^* X}{M_*^2} Q^* Q + \ldots\right]_{\theta^4} + \left[\frac{X}{M_*} QUH_u + \ldots\right]_{\theta^2}$$

gaugino masses — scalar masses — scalar trilinear

$$+ \left[\frac{X^*}{M_*} H_u H_d + \frac{X^* X}{M_*^2} H_u H_d\right]_{\theta^4} + \ldots$$

μ — B_μ

Weak scale masses: $M_a \sim \mu \sim \frac{F_X}{M_*}$, $m^2 \sim B_\mu \sim \frac{F_X^2}{M_*^2}$ $\quad F_X \sim (10^{10}\text{GeV})^2$

Do we know these masses are flavor universal?

— We don't. … outside the realm of effective field theory

String theory might address the issue

- Dilaton domination
- No-scale ~~SUSY~~
- Moduli mediation

… Not completely clear

mSUGRA ansatz

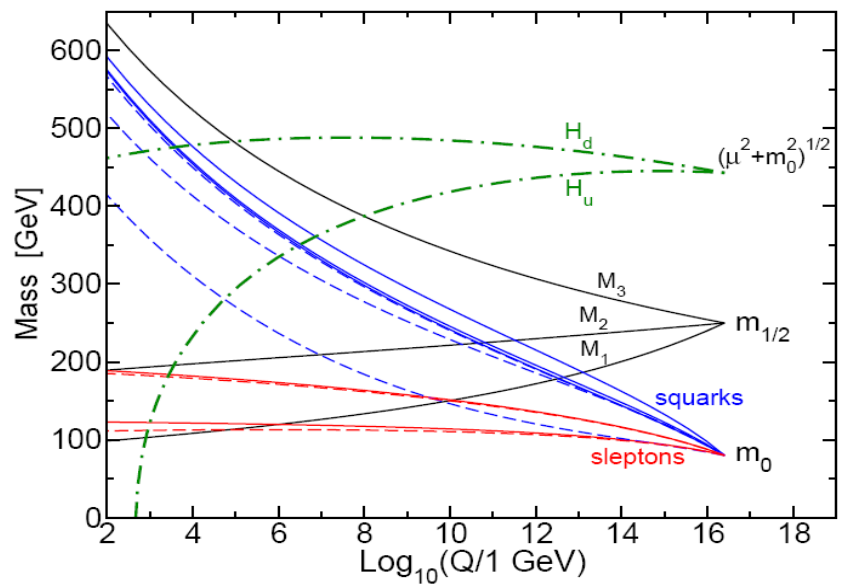
$M_1 = M_2 = M_3 = M_{1/2}$

$m_{\tilde{q}}^2 = m_{\tilde{u}}^2 = m_{\tilde{d}}^2 = m_{\tilde{l}}^2 = m_{\tilde{e}}^2 = m_0^2 \mathbf{1}$

$m_{h_u}^2 = m_{h_d}^2 = m_0^2$

$(a_{u,d,e})_{ij} = a_0 (y_{u,d,e})_{ij}$

at the scale $M_* \sim M_{Pl}$

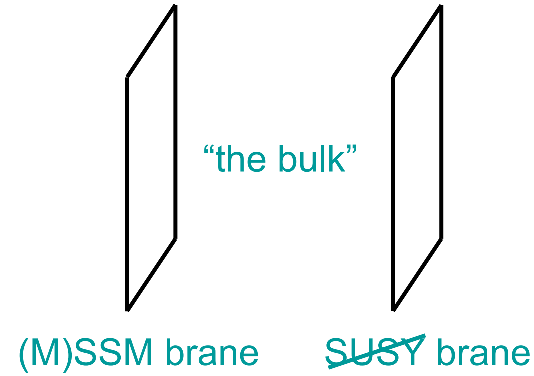


… 5 free parameters: $M_{1/2}$, m_0^2, a_0, μ, B_μ

Sequestering ~~SUSY~~

Randall, Sundrum ('98)

Dangerous (~~flavor~~) operators can be suppressed if ~~SUSY~~ and (M)SSM sectors are geometrically separated

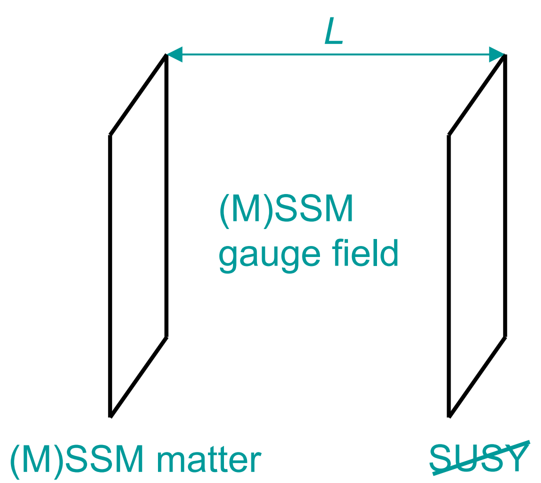


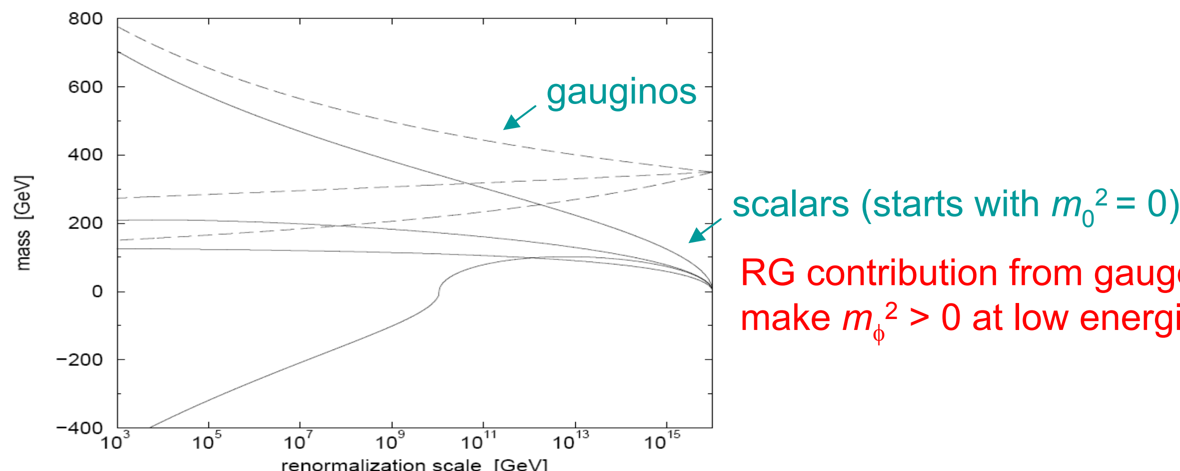
In fact, this suppresses all contact interactions

→ need some "mediator"

Gaugino mediation

Kaplan, Kribs, Schmaltz ('99); Chako, Luty, Nelson, Ponton ('99)





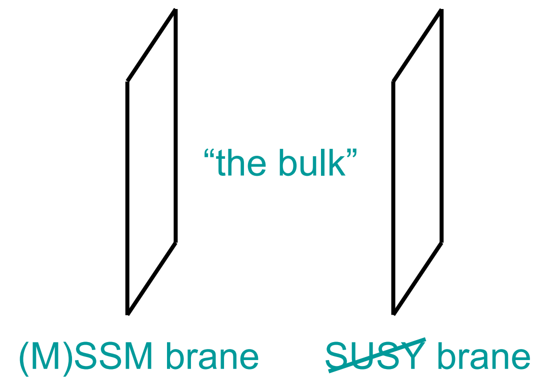
RG contribution from gauge loop make $m_\phi^2 > 0$ at low energies

→ $M_{1/2} \neq 0$, $m_0^2 \sim 0$ at the scale $M_* \sim 1/L$ ($\sim M_{Pl}$)

Flavor universal masses at low energies

Anomaly mediation

Randall, Sundrum ('98); Giudice, Luty, Murayama, Rattazzi ('98)



Gravity propagates between branes

→ produces soft masses in the (M)SSM sector at loop level

Gravity couples (only) to masses

In the (M)SSM with $\mu \to 0$, the only mass is the cutoff scale, which appear associated with divergences (β, γ functions)

$$\Longrightarrow \quad M_a = \frac{b_a g_a^2}{16\pi^2} m_{3/2}, \quad m_\phi^2 = \frac{c_a^\phi b_a g_a^4}{2(16\pi^2)^2} m_{3/2}^2, \quad \dots$$

← tachyonic sleptons

$m_{3/2} = O(100\,\mathrm{TeV})$

UV insensitivity: expressions does not depend on scales

Realistic Models

- Nondecoupling thresholds — Pomarol, Rattazzi ('99)
- U(1) *D*-term contributions — Arkani-Hamed, Kaplan, Murayama, Y.N. ('00) → UV insensitivity
- Mixed with moduli mediation — Choi, Falkowski, Nilles, Olechowski, Pokorski ('04) → mirage phenomenon

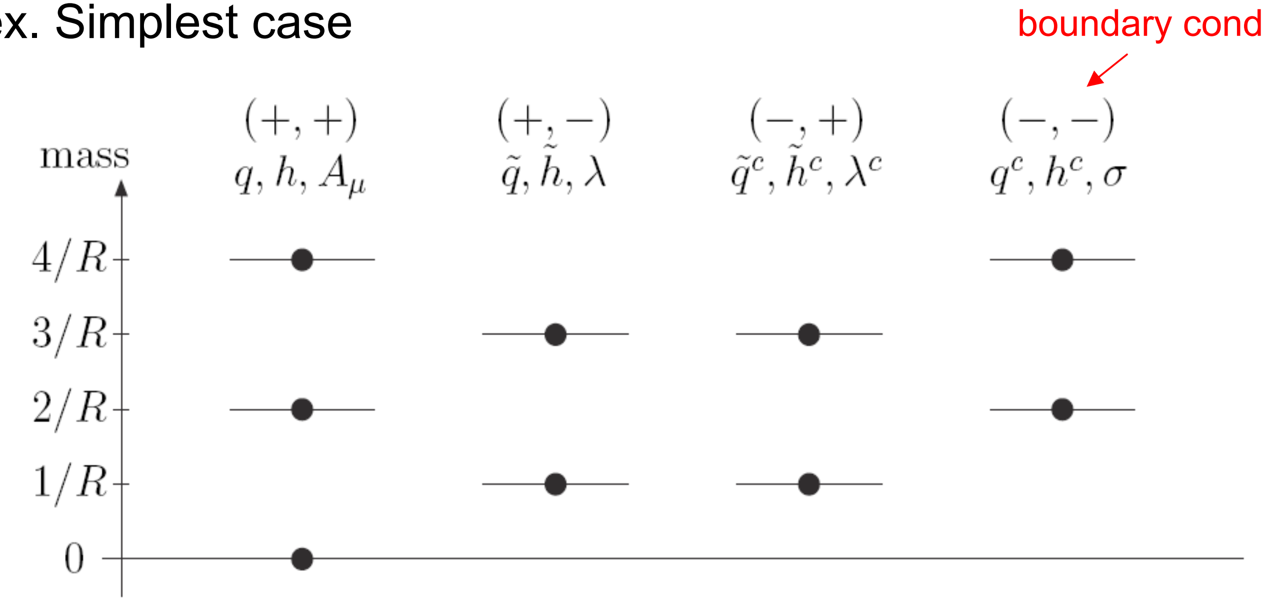
Problem of large B_μ … need some mechanism (*e.g.* NMSSM)

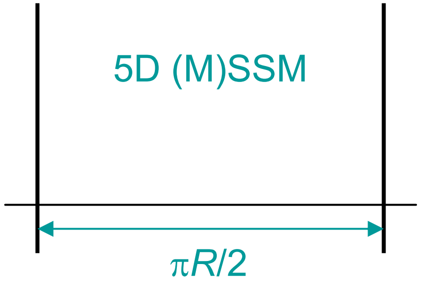
~~SUSY~~ from TeV scale extra dimensions

Pomarol, Quiros ('98);
Barbieri, Hall, Y.N. ('00); …

Supersymmetry can be broken by
boundary effects of a compact ~ TeV extra dimensions

ex. Simplest case





Radiative corrections to soft masses finite!

$\mathcal{N}$= 2 SUSY Kaluza-Klein towers ~ TeV

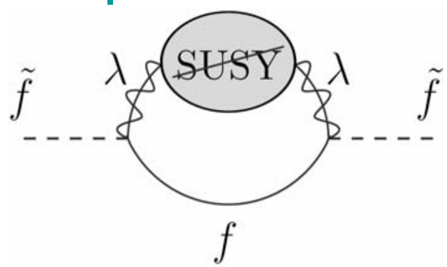
(Simplest implementation of gauge coupling unification is lost)

Gauge mediation

Dine, Fischler ('82); Alvarez-Gaume, Claudson, Wise ('82); Dimopoulos, Raby ('83); …

~~SUSY~~ sector may be charged
under the standard model gauge group

Standard model gauge loop



→ gaugino and scalar masses

Scalar masses arise from gauge loop
⟹ automatically flavor universal

$$M_a \sim \frac{g^2}{16\pi^2}\frac{F_{\rm mess}}{M_{\rm mess}}, \quad m_\phi^2 \sim \frac{g^4}{(16\pi^2)^2}\frac{F_{\rm mess}^2}{M_{\rm mess}^2} \qquad (M_a \sim m_\phi,\ m_\phi^2 > 0)$$

For $F_{\rm mess}/M_{\rm mess} \gg F_{\rm fund}/M_*$, gauge mediation contribution
completely dominate over (unwanted) Planck-suppressed contribution

How to realize?

Did not seem easy

- Avoid Landau pole for the (M)SSM gauge group
- Constraint from *R* symmetry in DSB
- Need of *R* symmetry breaking to generate gaugino masses
- …

Perturbative messenger paradigm

could be manifestation of a strong dynamics

$$W = (M_{\text{mess}} + \theta^2 F_{\text{mess}}) f \bar{f}$$

SUSY mass ~~SUSY~~ mass messenger fields

$$\Longrightarrow \quad M_a = N_{\text{mess}} \frac{g_a^2}{16\pi^2} \frac{F_{\text{mess}}}{M_{\text{mess}}}, \quad m_{\tilde{f}}^2 = 2 N_{\text{mess}} \sum_a C_a^{\tilde{f}} \left(\frac{g_a^2}{16\pi^2} \right)^2 \left| \frac{F_{\text{mess}}}{M_{\text{mess}}} \right|^2$$

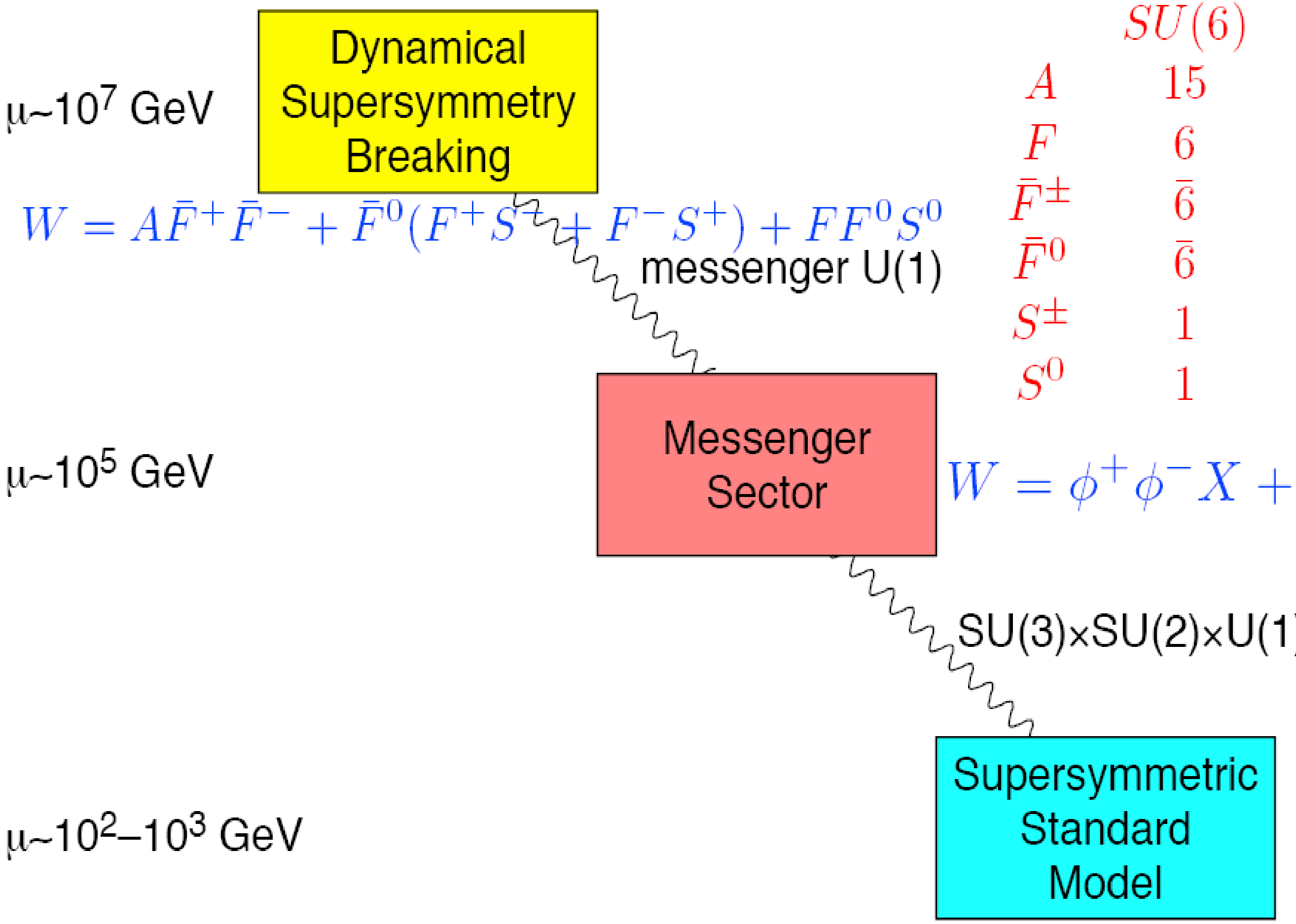
(Gauge coupling unification preserved if messengers fill complete SU(5) multiplets)

DSB + perturbative messengers

Dine, Nelson ('93); Dine, Nelson, Shirman ('94); Dine, Nelson, Nir, Shirman ('95); …

An early model

Dine, Nelson, Nir, Shirman ('95)



$$W = A\bar{F}^+\bar{F}^- + \bar{F}^0(F^+S^- + F^-S^+) + FF^0S^0$$

	$SU(6)$	$U(1)$	$U(1)_m$	$U(1)_R$
A	15	$+2$	0	$-\frac{18}{7}$
F	6	-5	0	$-\frac{18}{7}$
$\bar{F}^\pm$	$\bar{6}$	-1	± 1	$\frac{16}{7}$
$\bar{F}^0$	$\bar{6}$	-1	0	$\frac{16}{7}$
$S^\pm$	1	$+6$	± 1	$\frac{16}{7}$
S^0	1	$+6$	0	$\frac{16}{7}$

$$W = \phi^+\phi^-X + X^3 + X\bar{f}f$$

Significant complication to make the model realistic

Gauge mediation simplified

Murayama, Y.N. ('06)

Gauge theory G
(SUSY QCD)

SUSY SM

$m\bar{Q}Q$ $\quad\quad$ $M\bar{f}f$

most general superpotential

$$W = \frac{1}{M_*}\bar{Q}Q\,\bar{f}f + \ldots$$

- No *R* symmetry imposed

  (most general superpotential consistent with gauge symmetry)

- ~~SUSY~~ as well as successful gauge mediation occur

  for wide choice of gauge groups, matter content

  $N_c < N_f < 3N_c/2$
  for $G = \mathrm{SU}(N_c)$

Gauge mediation of ~~SUSY~~ as well as DSB

as generic phenomena in the landscape of SUSY theories

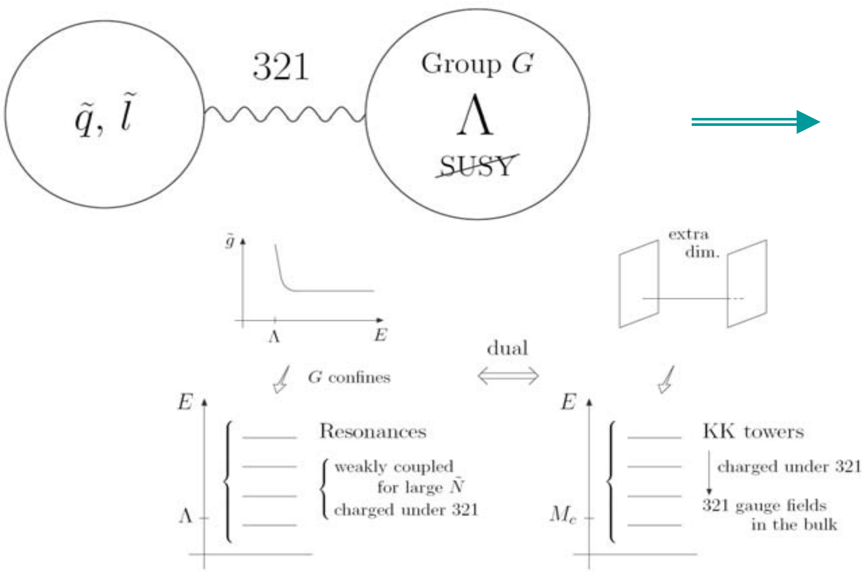
Gravitino is light

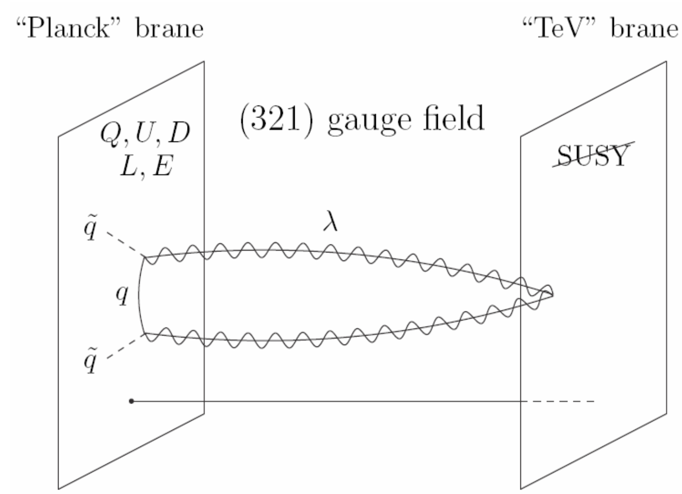
(M)SSM superparticles $\sim \dfrac{F_{\text{mess}}}{M_{\text{mess}}}$ Gravitino $\sim \dfrac{F_{\text{fund}}}{M_{\text{Pl}}}$

$M_{\text{mess}} \ll M_{\text{Pl}} \to m_{3/2} \ll m_{\lambda,\tilde{q},\tilde{l}}$

AdS realization

Y.N., hep-ph/0410348





μ-$B\mu$ problem

μ is not generated by gauge mediation

… generated by direct coupling of $H_{u,d}$ to ~~SUSY~~

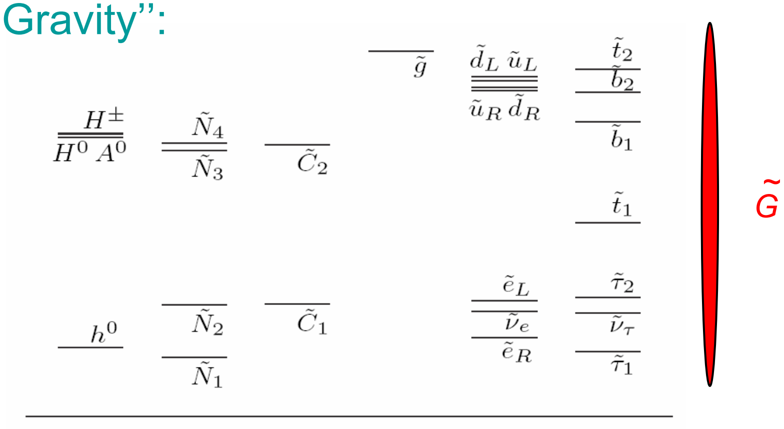
typically generate both μ and B_μ at 1 loop

- μ at 1 loop and B_μ at 2 loops
  Dvali, Giudice, Pomarol ('96); Giudice, Kim, Rattazzi ('07); …
- Hidden sector RG effect
  Roy, Schmaltzl ('07); Murayama, Y.N., Poland ('07)
- Large $m_{H_d}^2 \gg B_\mu$
  Csaki, Falkowski, Y.N., Volansky ('08)

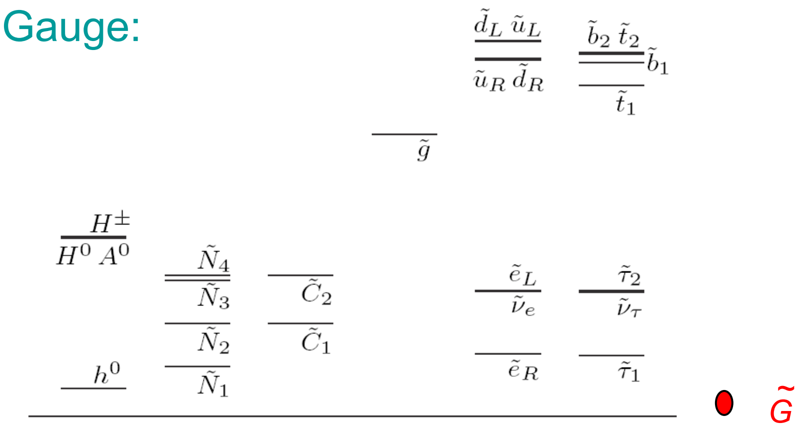
Phenomenology

A variety of phenomenology is obtained already with the mechanisms discussed

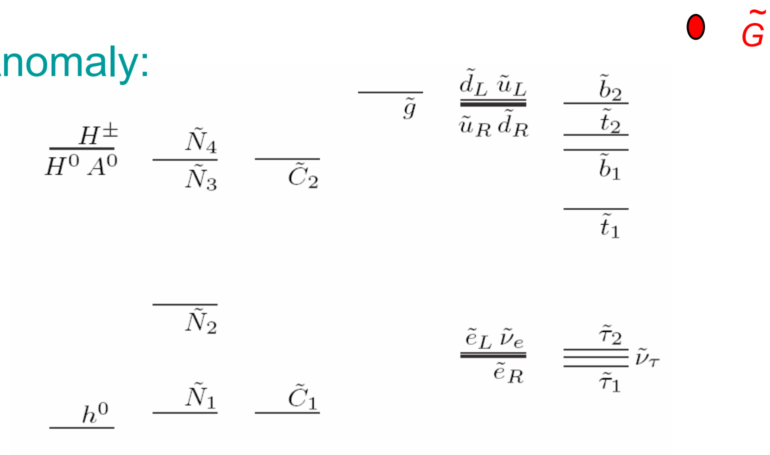
"Gravity":



Gauge:



Anomaly:

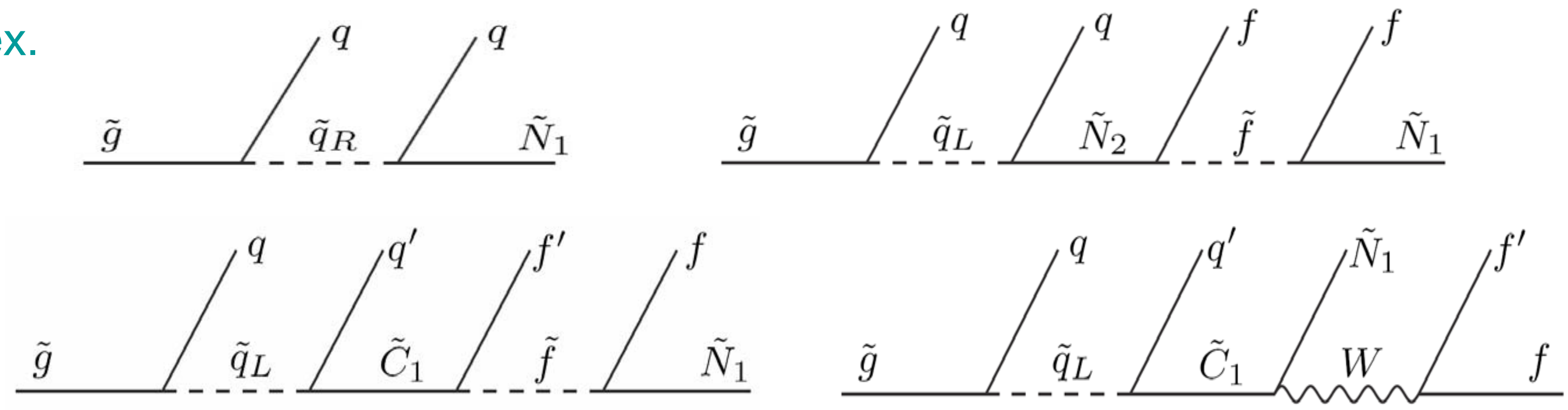


Range of the gravitino mass spans many orders of magnitude: ~ 0.1 eV – 100 TeV

“Canonical” signatures

Jets, leptons + $\not{E}_T$ from cascades

ex.



Variety of “non-canonical” signatures (by no means more “unlikely”)

Prompt decay of the lightest $\tilde{N}$ in gauge med.

$$\Gamma(\tilde{N}_1 \to \gamma \tilde{G}) = 2 \times 10^{-3}\, \kappa_{1\gamma} \left(\frac{m_{\tilde{N}_1}}{100\ \mathrm{GeV}} \right)^5 \left(\frac{\sqrt{\langle F \rangle}}{100\ \mathrm{TeV}} \right)^{-4} \mathrm{eV} \longrightarrow \gamma + \not{E}_T \text{ (+ leptons)}$$

($\kappa_{1\gamma}$: photino fraction)

Stable charged particle (NLSP $\tilde{l}$) decaying into $\tilde{G}$ outside the detector

→ highly ionizing and/or anomalously long TOF tracks

…

Any hint from available data?

Little hierarchy problem

$M_{\mathrm{Higgs}} > 114$ GeV

typically requires

$m_{\tilde{t}} \gtrsim 1$ TeV

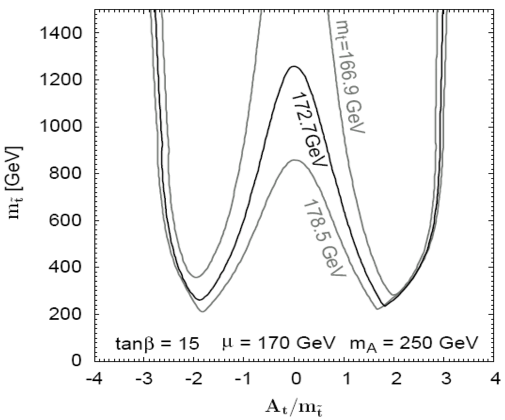
$$\longrightarrow \quad \delta m_h^2 \approx -\frac{3y_t^2}{4\pi^2} m_{\tilde{t}}^2 \ln \frac{\Lambda}{m_{\tilde{t}}}$$

… too large $\delta m_h{}^2$

→ fine-tuning

This may be hinting at particular MSSM region

Kitano, Y.N. ('06)



Large $A_t/m_{\tilde{t}}$

Small $m_{\tilde{t}}$

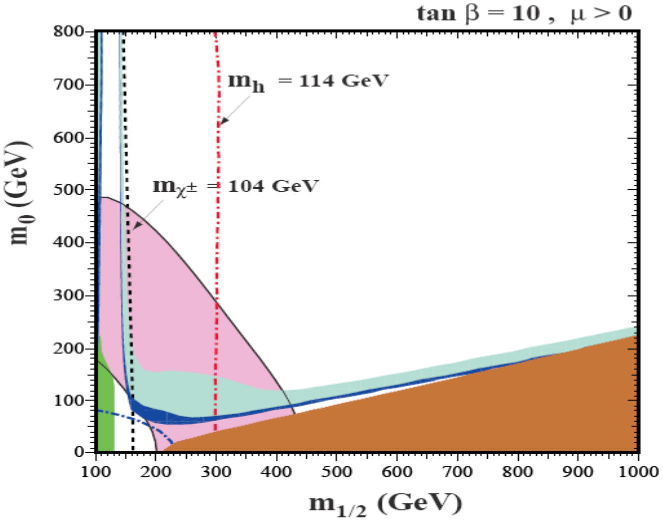
Particular MSSM parameter space ("golden region")

Kitano, Y.N. ('06); Perelstein, Spethmann ('07); …

- Large A_t
- Small $m_{\tilde{t}}$
- Light Higgs
- Small μ, $B\mu$

Cosmology

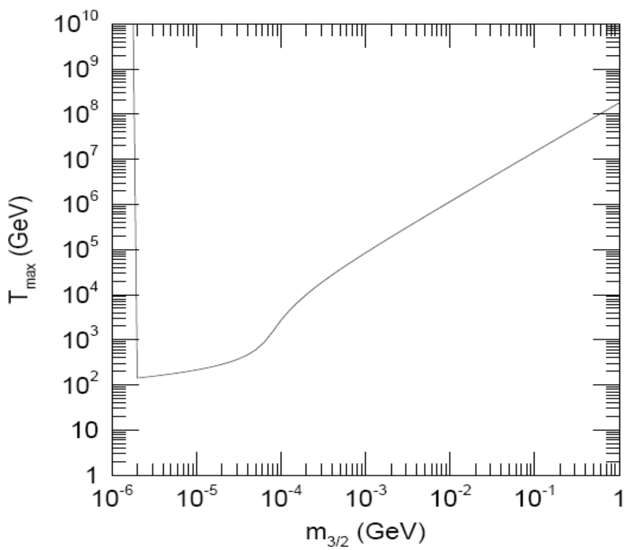
Lightest $\tilde{N}$ DM



Ellis, Olive, Santoso, Spanos

bulk region, stau coannihilation region, focus point region, *A*-pole region, …

Effects of the LSP $\tilde{G}$



de Gouvea, Moroi, Murayama

upper bound on the reheating temperature after inflation

Conclusions

Despite many alternatives, SUSY is (still)
the leading candidate for physics beyond the SM

Many beautiful features

spacetime symm., gauge coupling unif., radiative EWSB, …

Issue is SUSY breaking

origin (of the scale), flavor, *CP*, …

SUSY as well as (various) mediation seem generic

"gravity" mediation, gauge mediation, …

Will this be a triumph of human imagination,
or one of (many) unsuccessful ideas?

Experiments will tell us (LHC, LC, DM exp., …)