

# The Role of the Messenger Scale in Gauge-Mediated SUSY Breaking

Chris Wymant

IPPP, Durham University

4<sup>th</sup> April 2011

hep-ph/9709356 by Stephen P. Martin, Chapter 1

# Why Gauge-Mediated SUSY?

Supertrace theorem  $\Rightarrow$  SUSY broken in a hidden sector, effects communicated to the visible sector by e.g. gauge or gravity interactions.

Gauge mediation: Standard Model gauge interactions transmit the breaking of SUSY.

Pro vs. gravity mediation: absence of FCNC is automatic.

Con vs. gravity mediation: 'correct' Higgs mass parameters not automatic.

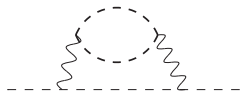
(hep-ph/9801271 by Giudice & Rattazzi)

# The Simplest Example

A single SU(5)-fundamental messenger. Its coupling to both the ~~SUSY~~ SUSY sector (with  $F$ -term vev  $\langle F_X \rangle$ ) and the SM superpartners generates soft mass terms for the latter:



→ gaugino masses (at  $\mathcal{O}(\alpha_{SM})$ ),



(plus 7 others) →

sfermion masses  
(mass<sup>2</sup> at  $\mathcal{O}(\alpha_{SM}^2)$ ),

all in terms of one mass scale  $\Lambda \equiv \frac{\langle F_X \rangle}{M_{\text{messenger}}}$ .

So-called *Minimal* or *Ordinary* Gauge Mediation.

*General Gauge Mediation*<sup>1</sup> 'GGM': defined as the collection of all theories that, in the limit  $\alpha_{SM} \rightarrow 0$ , decouple into the MSSM and a separate hidden sector that breaks SUSY.

Independent contributions from the three gauge groups to the gaugino masses and to the sfermion masses.

A parameter space of six mass scales –  $\Lambda_{G,r}, \Lambda_{S,r}$   
( $r = 1, 2, 3$  the gauge group).

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<sup>1</sup>hep-ph/0801.3278: P. Meade, N. Seiberg, D. Shih

$$M_r = \frac{\alpha_r}{4\pi} \Lambda_{G,r}$$

$$m_{\tilde{f}}^2 = 2 \sum_{r=1}^3 C_2(f, r) \left( \frac{\alpha_r}{4\pi} \right)^2 \Lambda_{S,r}^2$$

( $C_2(f, r)$  the quadratic Casimir operators)

Two sum rules:

$$\text{Tr}[Ym^2] = 0 = \text{Tr}[(B - L)m^2]$$

$$\begin{aligned} \text{i.e.} \quad m_Q^2 - 2m_U^2 + m_D^2 - m_L^2 + m_E^2 &= 0 \\ 2m_Q^2 - m_U^2 - m_D^2 - 2m_L^2 + m_E^2 &= 0 \end{aligned}$$

# Concept of *Running* $\Lambda_{S,r}(Q)$

The sum rules are still valid at the electroweak scale for the lighter two generations<sup>2</sup>.

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<sup>2</sup>hep-ph/1103.1843: J. Jaeckel, V. V. Khoze, C. Wymant

# Concept of *Running* $\Lambda_{S,r}(Q)$

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RG invariants involving the (running) couplings, gaugino masses and first generation sfermion masses

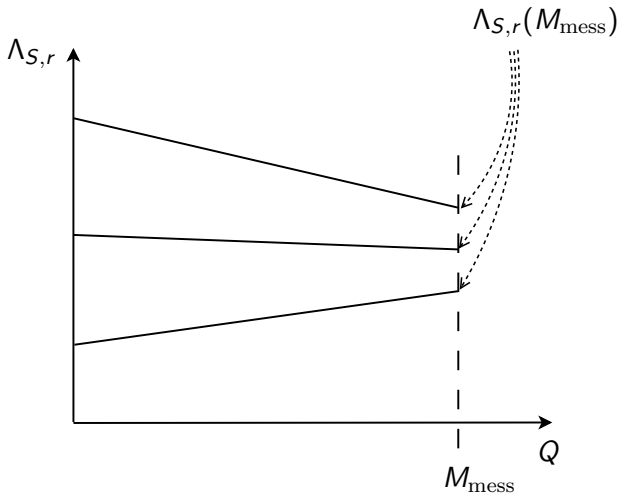
→ an expression for running  $\Lambda_{S,r}(\mathbf{Q})$ .

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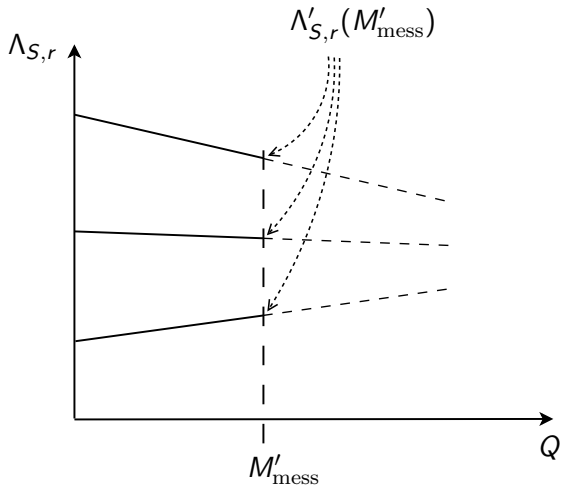
<sup>2</sup>hep-ph/1103.1843: J. Jaeckel, V. V. Khoze, C. Wymant



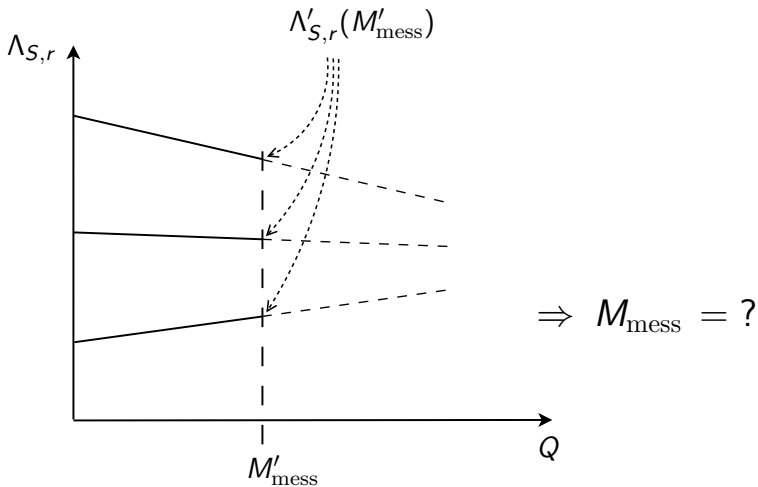
# Equivalence of Models (i)



# Equivalence of Models (ii)



# Equivalence of Models (ii)



# The Third Generation

Take RG invariants  $\rightarrow$  swap *third* generation sfermion masses in place of *first* generation sfermion masses  $\rightarrow$  no longer RG invariant.  
Flavour-blindness  $\Rightarrow$

at  $M_{\text{mess}}$  :      RG variants      =      corresponding RG *invariants*

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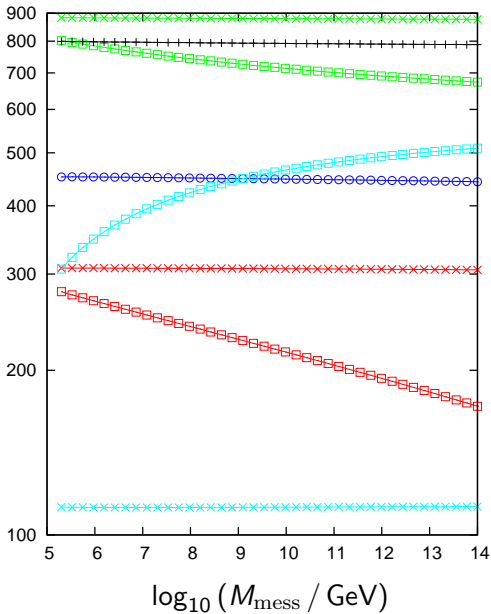
<sup>3</sup>hep-ph/1103.1843: J. Jaeckel, V. V. Khoze, C. Wymant

<sup>4</sup>hep-ph/0104145: B.C. Allanach





Mass  
(GeV)



# Unification

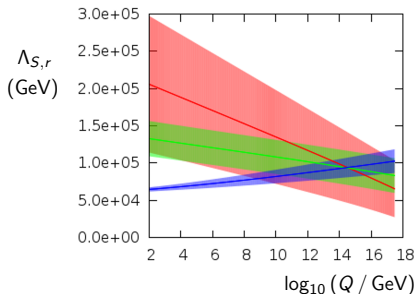
Messenger in complete and unsplit GUT multiplet  $\Rightarrow$  equal

$\Lambda_{S;r=1,2,3}$  at  $M_{\text{mess}}$ .

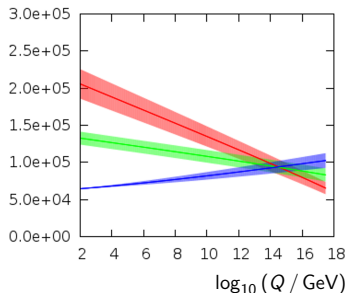
Low-scale sfermion & gaugino spectrum determines the running

$\Lambda_{S,r}(Q)$  up to high-scale values – can observe the unification!

Uncertainty in mass measurement dominates NLO RG effects.



1<sup>st</sup> gen. sfermion and gaugino  
soft masses known to 5%



$m_U$  and  $m_D$  known to 1%