Naturalness in General Gauge Mediation

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based on: Z. Lalak and ML, arXiv:1302.6546

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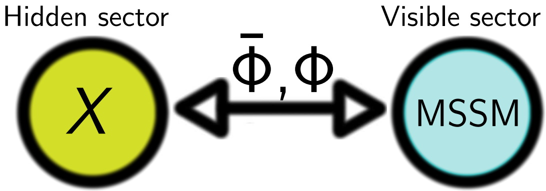
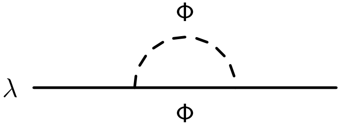
SUSY breaking mediation

- Supergravity
  - No control over mixing between families $\longrightarrow$ lagre FCNC

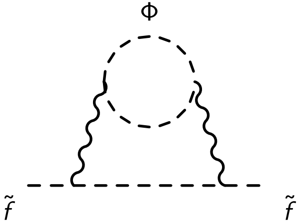
- Gauge mediation
  - SUSY is spontaneously broken$\longrightarrow$ singlet $\langle X \rangle = X + \theta^2 F$
  - breaking is transmitted through messengers $W = \lambda \bar{\Phi} X \Phi$
  - messengers $\bar{\Phi}$,Φ interact with MSSM fields only via gauge interactions



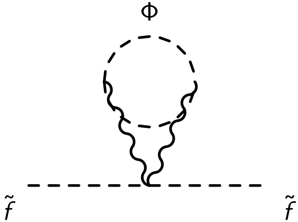
Gauge mediated soft terms



$$\Longrightarrow M_i = \frac{\alpha_i}{4\pi} \frac{F}{X}$$



$+$



$+ \ldots$

$$\Longrightarrow m_{\tilde{f}}^2 = 2 \sum_i C_i(f) \left(\frac{\alpha_i}{4\pi} \right)^2 \left| \frac{F}{X} \right|^2$$

GGM soft terms

Meade, Shih and Seiberg 0801.3278

Gauge mediated soft terms can be expressed by just six parameters

- Three gaugino masses

$$M_1 = \frac{\alpha_1}{4\pi} m_Y, \quad M_2 = \frac{\alpha_2}{4\pi} m_w, \quad M_3 = \frac{\alpha_3}{4\pi} m_c,$$

- Three parameters determining scalar masses Λ_c^2 , Λ_w^2 , Λ_Y^2 which give

$$m_f^2 = 2\left[C_3(f)\left(\frac{\alpha_3}{4\pi}\right)^2 \Lambda_c^2 + C_2(f)\left(\frac{\alpha_2}{4\pi}\right)^2 \Lambda_w^2 + C_1(f)\left(\frac{\alpha_1}{4\pi}\right)^2 \Lambda_Y^2\right],$$

- Only negligible A-terms are generated.

Implementations

Two specific models Carpenter et al. 0805.2944

- GGM1

$$W_{GGM1} = X_i(y^i \bar{Q}Q + r^i \bar{U}U + s^i \bar{E}E),$$

with three independent parameters Λ_Q,Λ_U,Λ_E

- GGM2

$$W_{GGM2} = X_i(y^i \bar{Q}Q + r^i \bar{U}U + s^i \bar{E}E + \lambda_q^i \tilde{q}q + \lambda_l^i \tilde{l}l),$$

with five independent parameters Λ_Q,Λ_U,Λ_E,Λ_q,Λ_l

fine-tuning definition

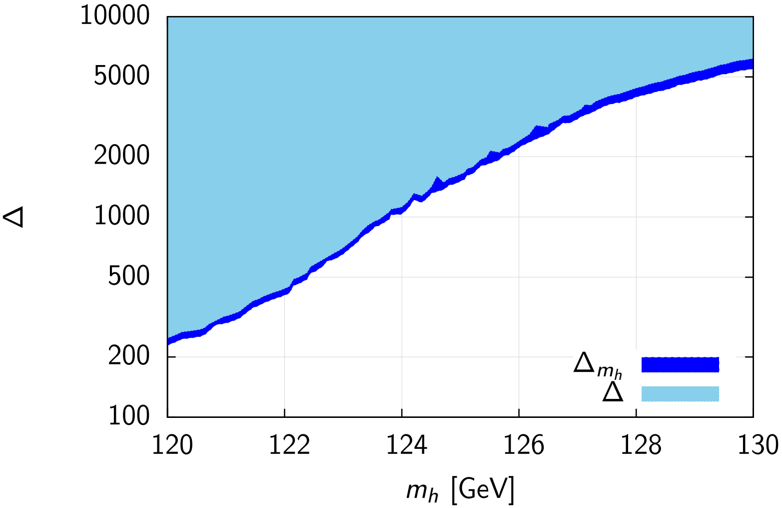
- fine-tuning from parameter a

$$\Delta_a = \left| \frac{\partial \ln m_Z^2}{\partial \ln a} \right| .$$

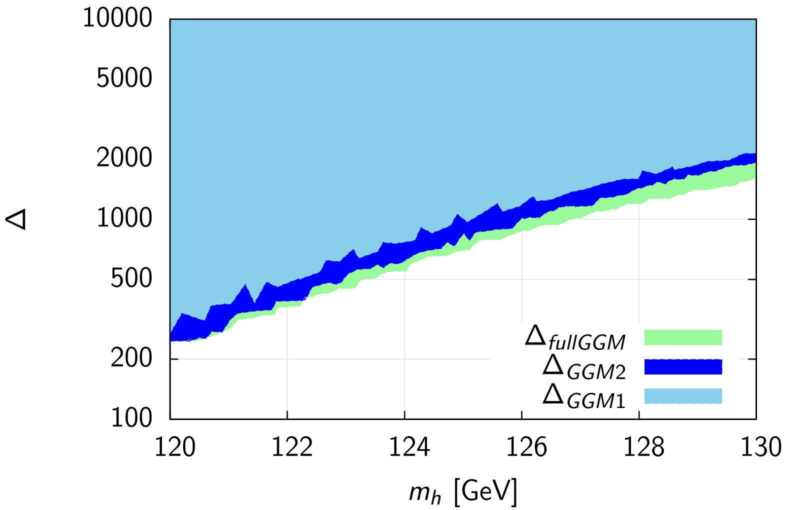
- fine-tuning coming from a whole set of parameters a_i

$$\Delta = \max_{a_i} \Delta_{a_i} .$$

FT in mSUGRA


10000
5000
2000
1000
500
200
100
Δ
120
122
124
126
128
130
m_h [GeV]
Δ_{m_h}
Δ

FT in GGM



10000
5000
2000
1000
500
200
100
Δ
120
122
124
126
128
130
m_h [GeV]
$\Delta_{fullGGM}$
Δ_{GGM2}
Δ_{GGM1}

reducing fine-tuning

Assuming that parameters are not independent of each other, but instead are functions of some fundamental parameters. For example, if gaugino masses M_i are given functions of parameter $M_{\frac{1}{2}}$ we obtain

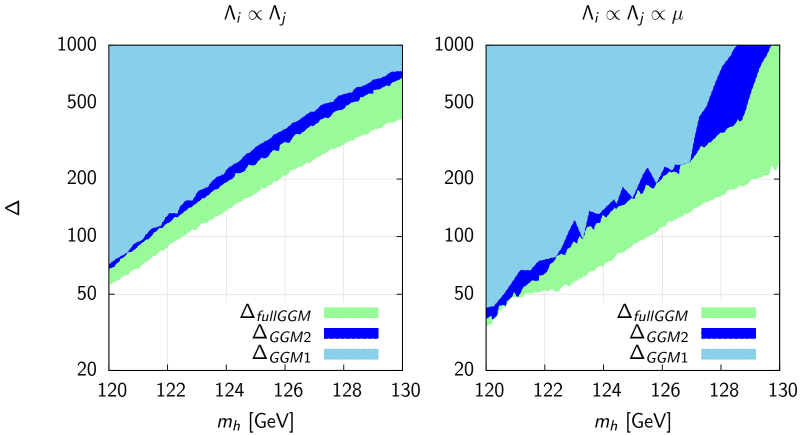
$$\begin{aligned} M_i &= f_i(M_{\frac{1}{2}}), \\ \Delta_{M_{\frac{1}{2}}} &= \left| \frac{\partial \ln M_Z^2}{\partial \ln M_{\frac{1}{2}}} \right| = \left| M_{\frac{1}{2}} \frac{f_i'(M_{\frac{1}{2}})}{f_i(M_{\frac{1}{2}})} \frac{\partial \ln M_Z^2}{\partial \ln M_i} \right| . \end{aligned}$$

If f_i are simply proportional to $M_{\frac{1}{2}}$ one finds

$$\Delta_{M_{\frac{1}{2}}} = \left| \sum_{i=1}^{3} \frac{\partial \ln M_Z^2}{\partial \ln M_i} \right| .$$

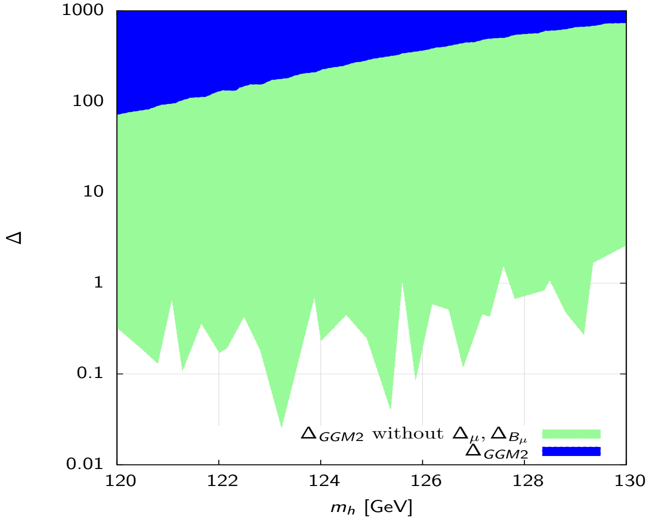
If these functions were logarithms

$$M_i(M_{\frac{1}{2}}) = \tilde{m} \ln \frac{M_{\frac{1}{2}}}{Q} \quad , \quad \Delta_{M_{\frac{1}{2}}} = \left| \sum_{i=1}^{3} \frac{\tilde{m}}{M_i} \frac{\partial \ln M_Z^2}{\partial \ln M_i} \right| .$$



$\Lambda_i \propto \Lambda_j$
$\Lambda_i \propto \Lambda_j \propto \mu$
Δ
1000
500
200
100
50
20
120
122
124
126
128
130
m_h [GeV]
$\Delta_{fullGGM}$
Δ_{GGM2}
Δ_{GGM1}

fine-tuning from only gauge mediated soft terms



Brummer and Buchmuller 1201.4338

Constraints from $g_\mu - 2$

- discrepancy between measurement and SM prediction:

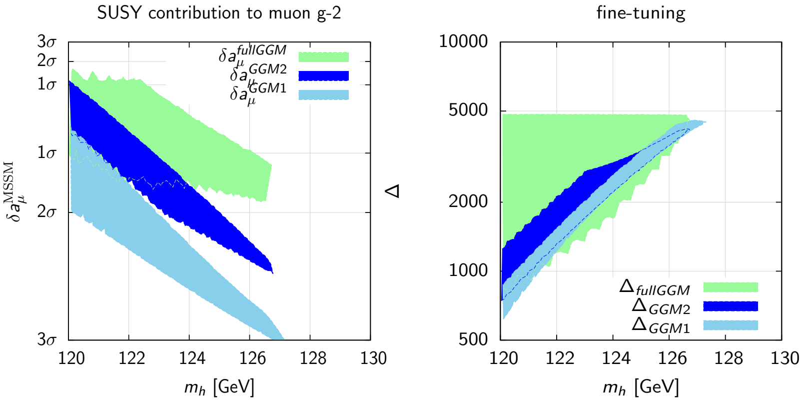
$$\delta a_\mu = a_\mu^{\mathrm{EXP}} - a_\mu^{\mathrm{SM}} = (2.8 \pm 0.8)10^{-9}.$$

- The simplest approximation of SUSY contribution

$$\delta a_\mu^{\mathrm{SUSY}} \approx \left(\frac{g_1^2 - g_2^2}{192\pi^2} + \frac{g_2^2}{32\pi^2} \right) \frac{m_\mu^2}{M_{\mathrm{SUSY}}^2} \operatorname{tg}\beta,$$

Problem:We need heavy superpartners (M_{SUSY})

$g_\mu - 2$ and FT



SUSY contribution to muon g-2
3σ
2σ
1σ
1σ
2σ
3σ
$\delta a_\mu^{\rm MSSM}$
$\delta a_\mu^{fullGGM}$
δa_μ^{GGM2}
δa_μ^{GGM1}
120 122 124 126 128 130
m_h [GeV]
fine-tuning
10000
5000
2000
1000
500
Δ
$\Delta_{fullGGM}$
Δ_{GGM2}
Δ_{GGM1}
120 122 124 126 128 130
m_h [GeV]

Conclusions

1. GGM predicts smaller fine-tuning than mSUGRA
2. for $m_h = 126$GeV fine-tuning always larger than 100 unless one includes only gauge mediated soft terms
3. including $g_\mu - 2$ raises fine-tuning about four times, but its still possible to obtain $g_\mu - 2$ within 1σ bound
4. decrease of the Higgs mass down to 123 GeV reduces the fine-tuning by a factor of 2.