# Asymptotically Safe Extensions of the MSSM

[Work in progress in collaboration with Gudrun Hiller and Daniel Litim]

DESY Theory Workshop 2019
Quantum field theory meets gravity

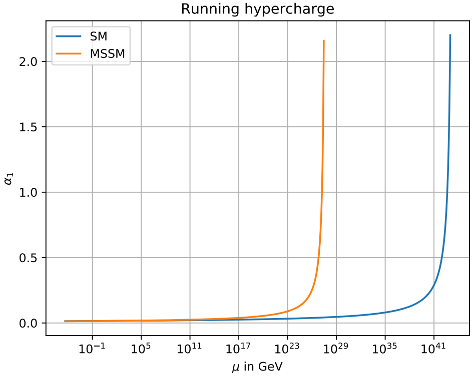
Kevin Moch

TU Dortmund

25.09.2019

# Motivation

- The Standard Model (SM) is not fundamental



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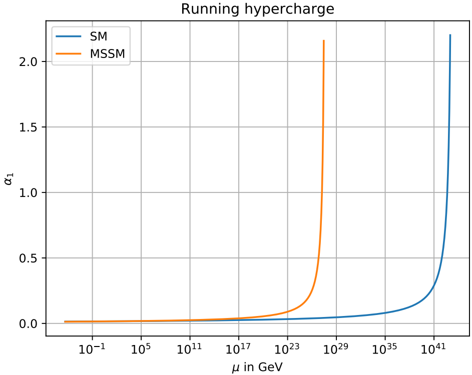


- Not only a perturbative artifact

[H. Gies and J. Jaeckel, 2004]

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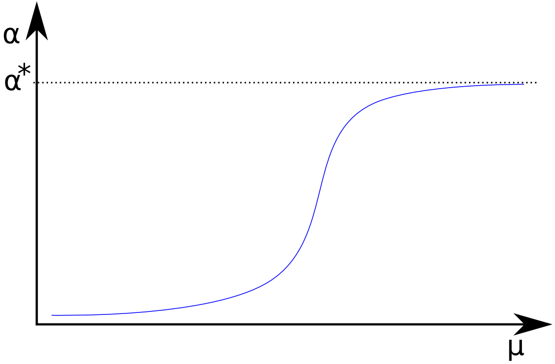

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- Also possible for the minimal supersymmetric SM (MSSM)?
- In the MSSM, also the $SU(2)_L$ coupling has a Landau pole

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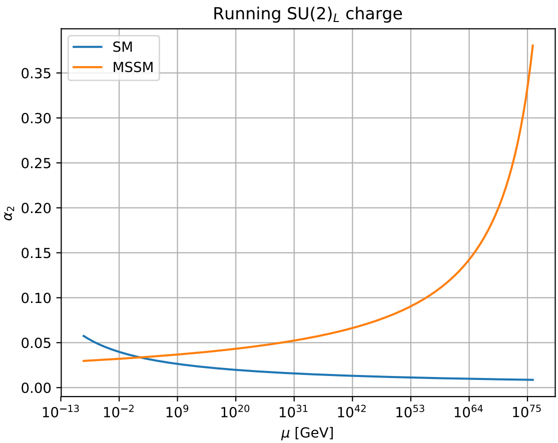


The MSSM is not AS, with or without $R$-parity violating terms.

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Loophole: Semi-simple gauge groups $\rightarrow$ AS SUSY models found (MSSM not yet included)

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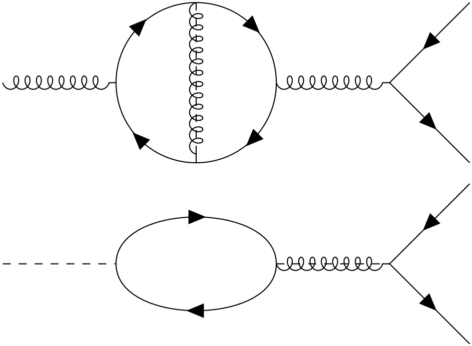
- Fixed point (FP) $\alpha^*$ with $\beta_i(\alpha^*) = 0$ physical and perturbative:

$$0 \leq \alpha_i^* < 1 \, .$$

$$\beta_i = \alpha_i^2 \Big[ -B_i + C_i \alpha_i + \sum_{j \neq i} C_{ij} \alpha_j - \sum_m D_{im} \alpha_{y_m} \Big],$$

$$\beta_{y_m} = \alpha_{y_m} \Big[ E_m \alpha_{y_m} + \sum_{n \neq m} E_{mn} \alpha_{y_n} - \sum_i F_{mi} \alpha_i \Big].$$



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More particles: $\boxed{B_i} \searrow$ , $C_i \nearrow$

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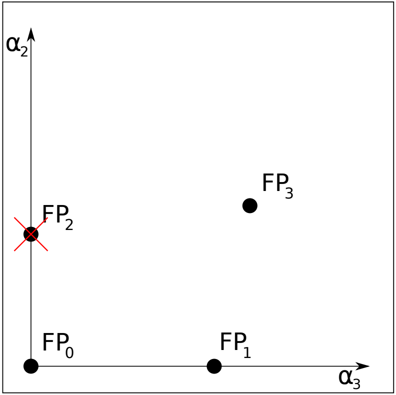
## Gauge group $SU(3)_C \otimes SU(2)_L$

$B_3 > 0$ , $B_2 < 0$:

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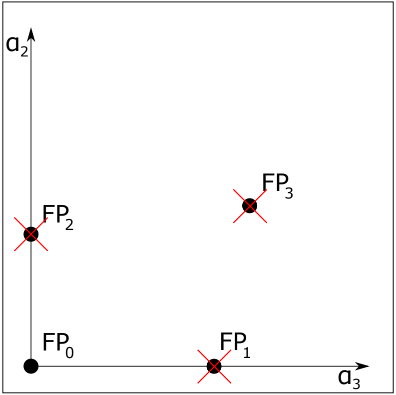

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$$B_3 > 0 \,, B_2 < 0 \,, B_1 < 0.$$

For $B_3$ to stay positive, we may only add the colored fields

1) One $\mathbf{3}$ and one $\overline{\mathbf{3}}$,
2) Two $\mathbf{3}$ and two $\overline{\mathbf{3}}$.

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4) MSSM + $4^{\text{th}}$ generation (1 quark doublet and 2 quark singlets)

# MSSM extensions

The four possible candidates for AS MSSM extensions are

1) MSSM + two quark singlets ← AS models found in scans
2) MSSM + four quark singlets ← No AS models found in scans
3) MSSM + two quark doublets ← No AS models found in scans
4) MSSM + $4^{\text{th}}$ generation ← No AS models found in scans

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# On UV/IR attractive directions

$$\beta_i(g)\Big|_{\alpha^*} \approx \sum_j M_{ij}(\alpha_j - \alpha_j^*) ,$$

with stability matrix

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If e.g. $\alpha_2^* = 0$:

$$\beta_2\big|_{\alpha^*} = -B_{2,\text{eff}}^{\alpha^*}\alpha_2^2 + \mathcal{O}(\alpha_2^3) \, , \; B_{2,\text{eff}}^{\alpha^*} = B_2 - C'_{23}\alpha_3^* - C'_{21}\alpha_1^* \, .$$

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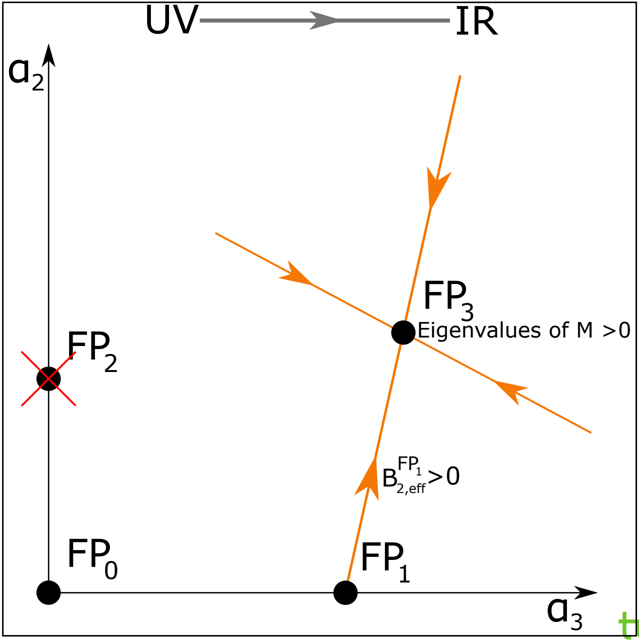
UV
IR
$a_2$
$FP_3$
Eigenvalues of M >0
$FP_2$
$B^{FP_1}_{2,eff} > 0$
$FP_0$
$FP_1$
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Scanning $\sim 3.600.000$ models yields 281 AS models with $FP_1$ UV, $FP_3$ IR.

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AS Example:

| Superfield | $SU(3)_C$ | $SU(2)_L$ | $U(1)_Y$ | Multiplicity |
|---|---|---|---|---|
| quark doublet $Q$ | $\mathbf{3}$ | $\mathbf{2}$ | $+\frac{1}{6}$ | 3 |
| up-quark $\overline{u}$ | $\overline{\mathbf{3}}$ | $\mathbf{1}$ | $-\frac{2}{3}$ | 3 |
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| up-Higgs $H_u$ | $\mathbf{1}$ | $\mathbf{2}$ | $+\frac{1}{2}$ | 1 |
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$$+ y_5 \overline{u}_2 Q_1 \overline{L}_1 + y_6 \overline{u}_1 Q_2 \overline{L}_2 + y_t \overline{u}_3 Q_3 H_u + y_b \overline{d}_3 Q_3 H_d$$

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→ R parity violation necessary!

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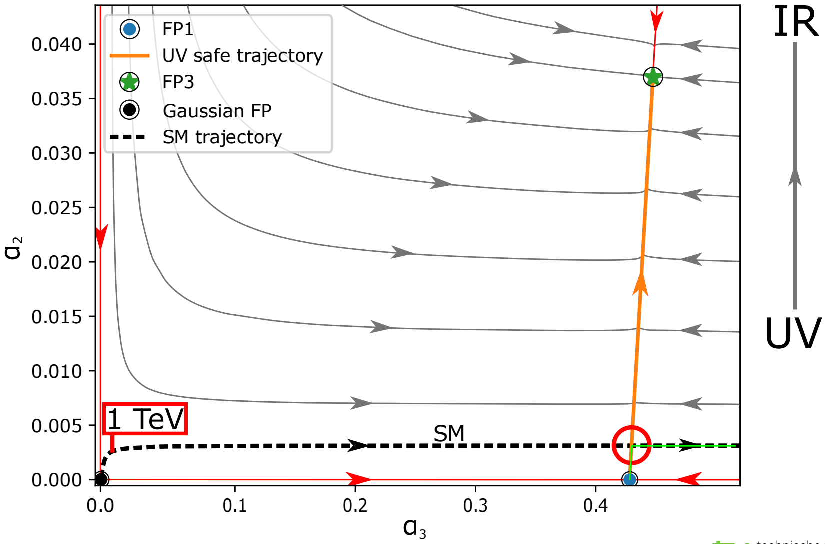
# General RG flow picture



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- $\mathrm{FP}_1\big|_{\alpha_3} > 3/110 \approx 0.027$
- $\mathrm{FP}_3$ exists $\Leftrightarrow$ $\mathrm{FP}_1$ exists and UV.
  $\rightarrow \mathrm{FP}_3\big|_{\alpha_3} > \mathrm{FP}_1\big|_{\alpha_3}$

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Matching onto the SM not possible at all!

# Non-perturbative checks

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- $\rightarrow$ Benchmarks are in agreement with exact SCFT relations

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Stay tuned!

[1] H. Gies and J. Jaeckel, Phys. Rev. Lett. **93** (2004) 110405 doi:10.1103/PhysRevLett.93.110405 [hep-ph/0405183].

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