New GUT Predictions for Quark and Lepton Yukawa Coupling Ratios

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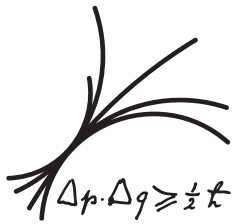

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in collaboration with Stefan Antusch and Stephen F. King

Outline

Motivation

GUT Predictions for Yukawa Coupling Ratios

What are the GUT Scale Yukawa Coupling Ratios?

A Flavour Model

Summary & Conclusions

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- The Flavour Puzzle
- Well motivated SM extension: SUSY GUTs
- How can these two points be combined?

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GUT Predictions for Yukawa Coupling Ratios

- Standard GUT relations for Yukawa couplings in $SU(5)$:
  - $F_3 T_3 \langle H_{\overline{5}} \rangle \to y_\tau / y_b = 1$
  - $F_2 T_2 \langle H_{\overline{45}} \rangle \to y_\mu / y_s = -3$ [Georgi, Jarlskog '79]

- New GUT relations for Yukawa couplings in $SU(5)$: [Antusch, MS '09]
  - $(F_3 \langle H_{24} \rangle)_{\mathbf{5}} \left(T_3 \langle H_{\overline{5}} \rangle\right)_{\overline{\mathbf{5}}} \to y_\tau / y_b = -3/2$
  - $(F_2 \langle H_{24} \rangle)_{\mathbf{5}} \left(T_2 \langle H_{\overline{45}} \rangle\right)_{\overline{\mathbf{5}}} \to y_\mu / y_s = 9/2$
  - $\left(F_2 \langle H_{\overline{5}} \rangle\right)_{\mathbf{10}} (T_2 \langle H_{24} \rangle)_{\overline{\mathbf{10}}} \to y_\mu / y_s = 6$

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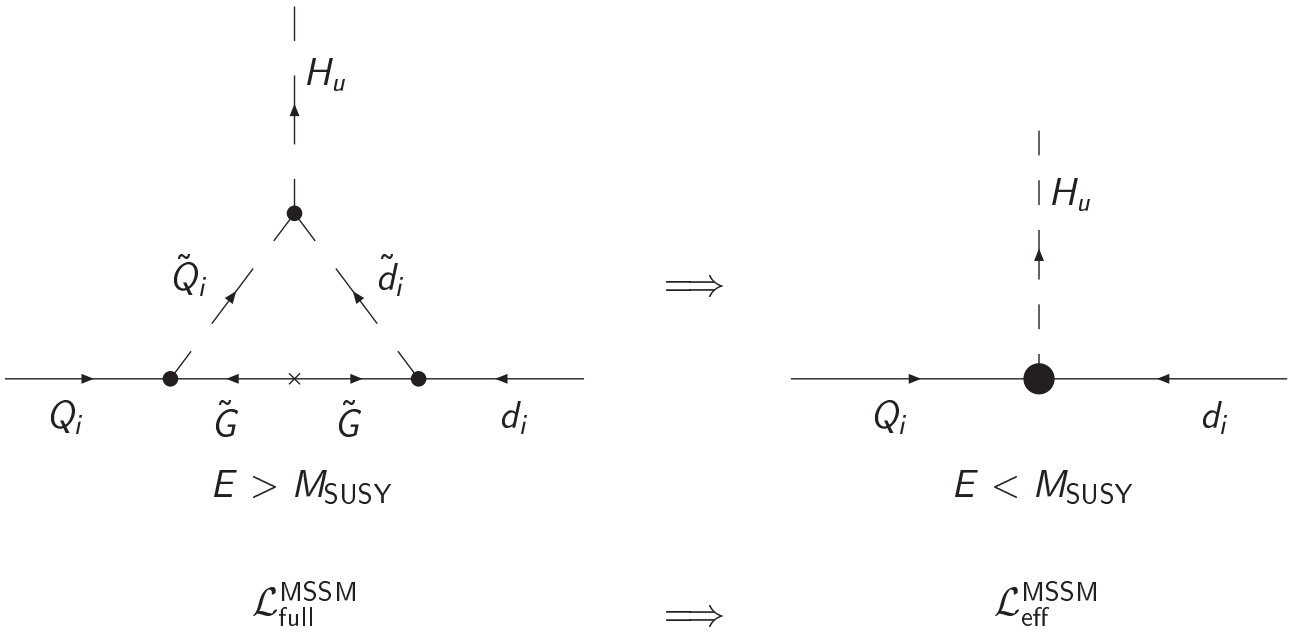
SUSY Threshold Corrections [Hall, Rattazzi, Sarid '93]



Charged lepton and down-type quark Yukawa coupling matching conditions:

$$y^{MSSM} = \frac{y^{SM}}{\cos\beta(1+\epsilon\tan\beta)}$$

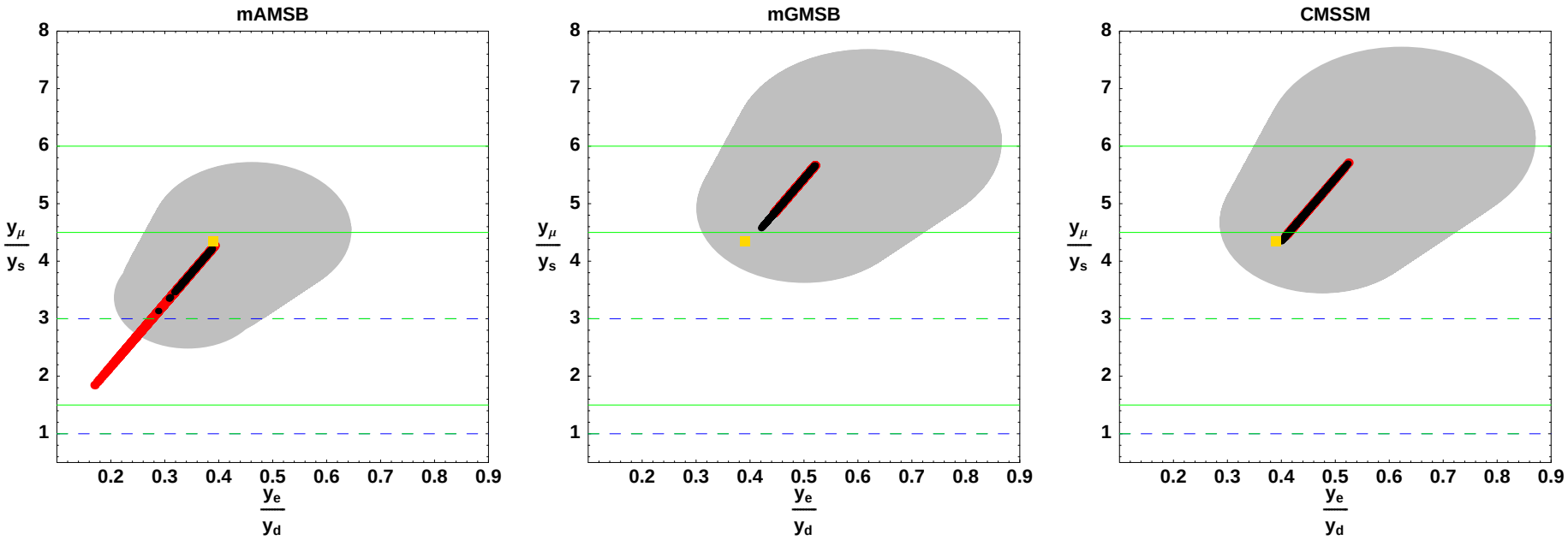
Changes GUT scale Yukawa coupling ratios! [Ross, Serna '07; Antusch, MS '08]

Phenomenological Analysis [Antusch, MS '09]

- We considered the following SUSY breaking scenarios:
  - mAMSB
  - mGMSB
  - CMSSM

- Applied phenomenological constraints:
  - Direct detection: Masses of $\chi^{\pm}$, $\tilde{l}$ and $\tilde{\nu}$ heavier than LEP bounds
  - EW precision observables:
    - $M_W = 80.429 \pm 0.039$ GeV
    - $\sin^2\theta_{eff} = 0.23153 \pm 0.00016$
  - $BR(b \to s\gamma) = \left(3.55^{+0.36}_{-0.37}\right) \times 10^{-4}$
  - $BR(B_s \to \mu^+\mu^-) \leq 5.8 \times 10^{-8}$
  - Anomalous magnetic moment of the muon: $0 \leq a_\mu \leq 35.9 \times 10^{-10}$

Results for the First and Second Generation



black: exp. allowed

grey: exp. uncertainties

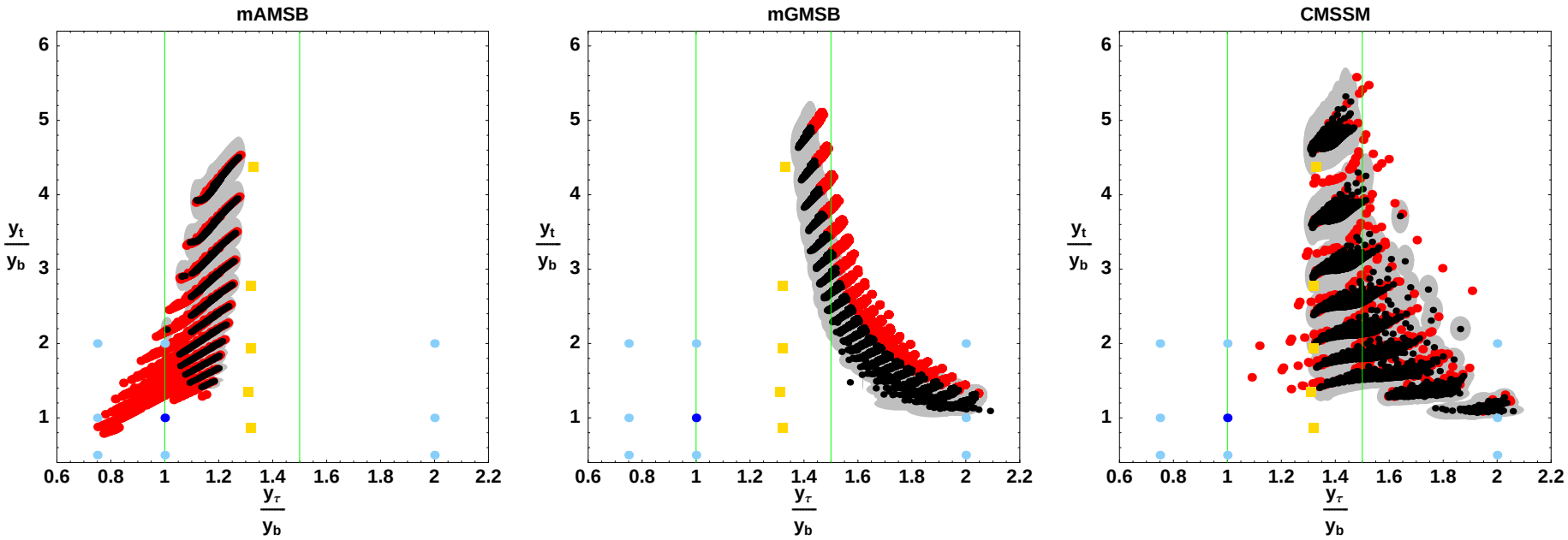
green: *SU*(5) predictions

red: exp. forbidden

yellow: no threshold corrections

blue: PS predictions

Results for the Third Generation



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Overview of GUT Scale Relations

Prediction	mAMSB	mGMSB	CMSSM
$y_\mu/y_s = 3$ †	✓	×	×
$y_\mu/y_s = 6$ △	×	✓	✓
$y_\mu/y_s = 9/2$ △	✓	✓	✓
$y_t = y_b = y_\tau$	×	×	×
$y_\tau/y_b = 1$	✓	×	×
$y_\tau/y_b = 3/2$ △	×	✓	✓
$2y_t = 2y_b = y_\tau$ ▽	×	✓	✓
$y_t = 2y_b = 2y_\tau$ ▽	✓	×	×

† [Georgi, Jarlskog '79]

△ [Antusch, MS '09]

▽ [Allanach *et al.* '97]

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The Model [Antusch, King, MS '10]

Symmetry:

$$A_4 \times SU(5) \times G_{\text{discrete}}$$

Matter:

$$F \equiv (\mathbf{3}, \overline{\mathbf{5}}, \ldots) \quad T_i \equiv (\mathbf{1}, \mathbf{10}, \ldots) \quad N_i \equiv (\mathbf{1}, \mathbf{1}, \ldots)$$

Flavons:

$$\phi_i \equiv (\mathbf{3}, \mathbf{1}, \ldots) \quad \tilde{\phi}_{23} \equiv (\mathbf{3}, \mathbf{24}, \ldots)$$

Higgs fields in $\mathbf{5}, \overline{\mathbf{5}}, \mathbf{15}, \overline{\mathbf{15}}, \mathbf{45}, \overline{\mathbf{45}}$ of $SU(5)$

Some messenger fields...

Alignment Ansatz, GUT Ratios and Fit

Ansatz for A_4 breaking:

$$\langle\phi_{23}\rangle \sim \begin{pmatrix} 0 \\ 1 \\ -1 \end{pmatrix}, \quad \langle\phi_{123}\rangle \sim \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}, \quad \langle\tilde{\phi}_{23}\rangle \sim \begin{pmatrix} 0 \\ \mathrm{i} \\ w \end{pmatrix}, \quad \langle\phi_3\rangle \sim \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}$$

Corresponding GUT Yukawa coupling ratios (y_l/y_q):

$$\phi_{23} \to 1\,, \quad \phi_{123} \to 1\,, \quad \tilde{\phi}_{23} \to 9/2\,, \quad \phi_3 \to 1$$

Fit:

$$11 \text{ parameters to } 13 \text{ observables} \to \chi^2/\text{dof} \approx 1.6$$

CP Phases

The quark CP phase precisely known from y_e, y_μ and θ_{12}^{CKM}:

$$\delta_{\text{CKM}}(M_{\text{GUT}}) \approx 68.2^\circ \quad (\delta_{\text{CKM}}^{\text{exp}}(M_{\text{GUT}}) \approx 68.8^\circ)$$

The leptonic CP phases:

$$\delta_{\text{MNS}}(M_{\text{GUT}}) \approx 90.0^\circ$$
$$\alpha_1(M_{\text{GUT}}) \approx 9.3^\circ$$
$$\alpha_2(M_{\text{GUT}}) \approx 0.0^\circ$$

Quasi-Degenerate Neutrino Masses

Neutrino mass matrix:

$$m_\nu = m_0 \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} + \frac{m_2'}{3} \begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix} + \frac{m_3'}{2} \begin{pmatrix} 0 & 0 & 0 \\ 0 & 1 & -1 \\ 0 & -1 & 1 \end{pmatrix}$$

m_0 generated by H_{15} resulting in possibly *quasi-degenerate* neutrinos

Results for Neutrinoless Double Beta Decay

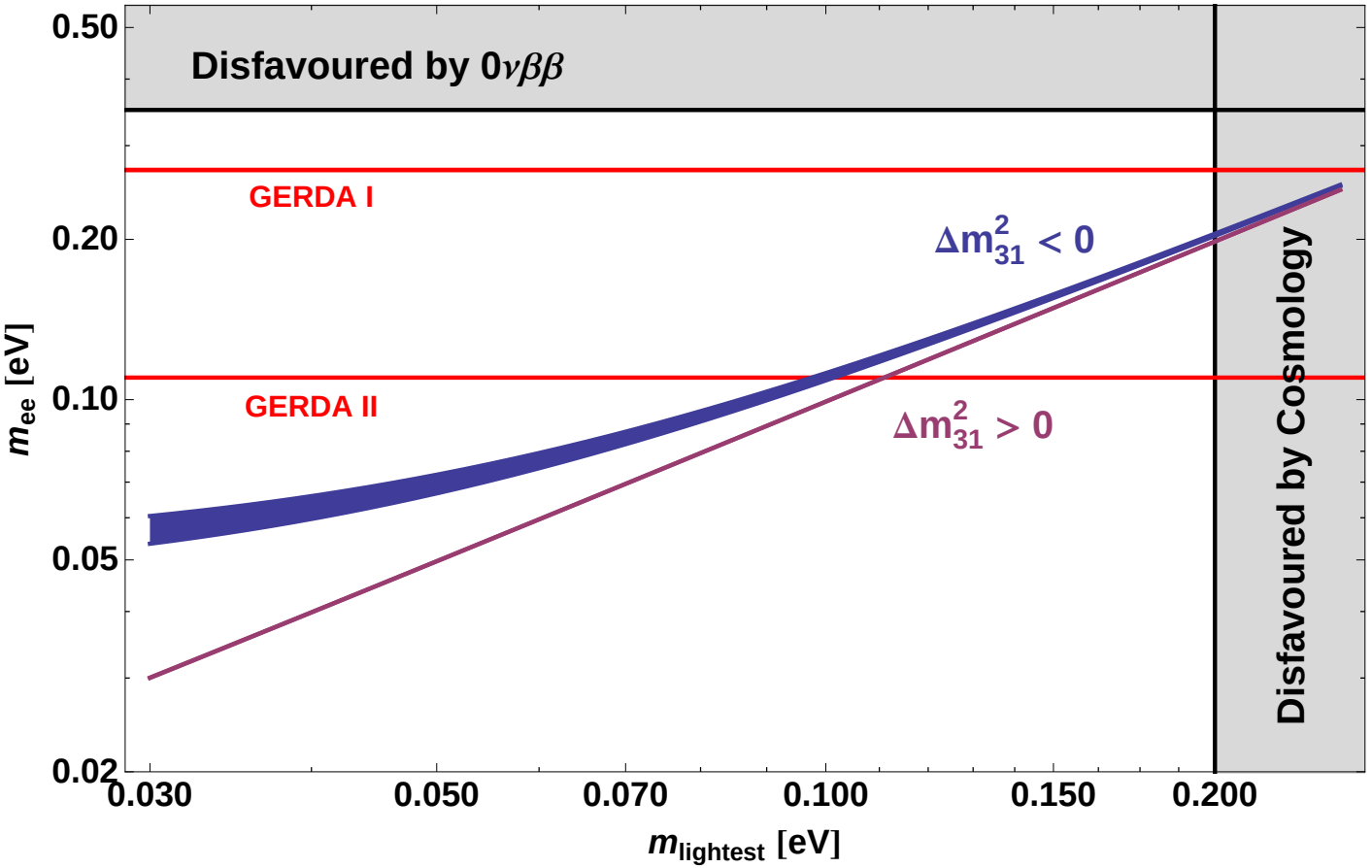

Figure: m_{ee} as a function of m_{lightest} in the model. [Antusch, King, MS '10]

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- New GUT Yukawa Coupling Ratios: [Antusch, MS '08-'09]
  - $y_\mu/y_s = 9/2$ or 6
  - $y_\tau/y_b = 3/2$
  - New Options for Model Building

- Explicit Application in a GUT Flavour Model: [Antusch, King, MS '10]
  - Quasi-degenerate Neutrino Masses
  - Spontaneous CP Violation
  - Testable Predictions

End of the talk

Thanks for your attention!