GUTs current status

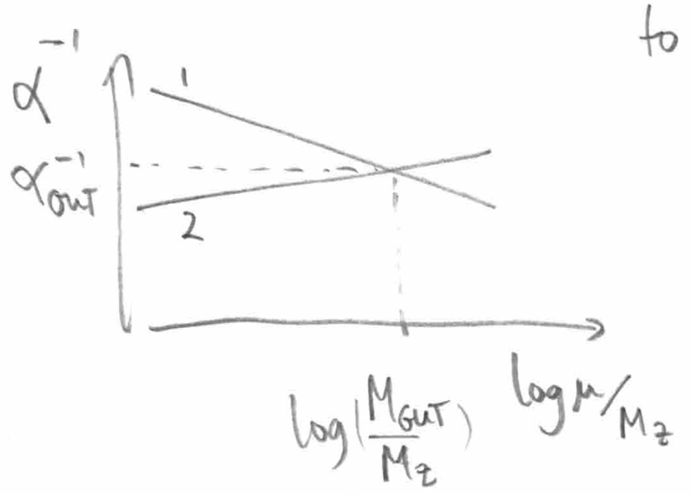
- predictions

1. Gauge coupling unification — SM no good
   \ MSSM works!

minimal SUSY extension to SM. Two Higgs doublets H_u, H_d and superpartners for all near the TEV scale.

The precision of the unification prediction?

Run up $\alpha_1^{-1}(\mu)$ & $\alpha_2^{-1}(\mu)$ to where they meet to determine α_{GUT}^{-1} and M_{GUT}



Then run down α_3^{-1} to m_Z and compare to experiment:

$$\alpha_s^{-1}(M_Z) = \alpha_{GUT}^{-1} + \frac{b_3}{2\pi} \log \frac{M_Z}{M_{GUT}} .$$

The prediction works and taking all uncertainties into account is about a 1% precision prediction. This is a success but could also be a coincidence?

2. Yukawa coupling unification

up type quark masses reside in $10\ 10\ 5_{H_u}$

down-type " " " " $10\ \bar{5}\ \bar{5}_{H_d}$

charged lepton " " " "

(SUSY requires a separate H_u and H_d)

$H_u = 5$, $H_d = \bar{5}$

$\Rightarrow$ predict unification $\lambda_b = \lambda_\tau$ at GUT-scale

after running down to m_b and m_τ one correctly predicts $\frac{m_b}{m_\tau}$!

However, the simplest models also predict

$\lambda_s = \lambda_\mu$ and $\lambda_d = \lambda_e$ both do not agree with experiment.

3. Charge quantization

by this is meant that the Hypercharges are all integer multiples of 1/6. (Recall $Q \sim 1/6$
$u^c \sim -2/3$
$D^c \sim 1/3$
$L \sim -1/2$
$E^c \sim 1$)

But this already follows from anomaly cancellation within the SM. i.e. the SM would be mathematically inconsistent if the hypercharges were not quantized in this way.

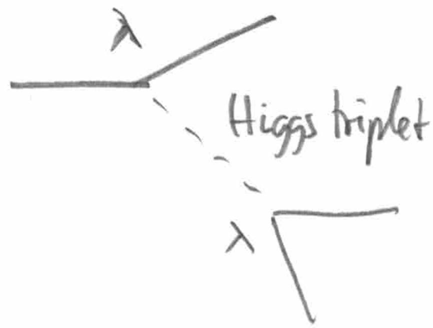
$\Rightarrow$ it is incorrect to say that GUTs explain charge quantization and the SM does not.

4. fermion content: • it's nice that one generation QUDLE fits into only two representations of SU(5) $10 + \bar{5}$

• in SO(10) its even nicer. There $16 = QUDLE + N$ ← RH neutrino

5. proton decay

$p \to \pi e^+$



$p \to K^+ \nu$

$K^0 e^+$

and other possible channel depending on details in yukawa couplings.

Minimal SUSY SU(5) prediction is already mostly ruled out. However, it's easy to avoid the bound with slight modifications of masses + couplings at the GUT scale.

in fact, it's possible to have GUT without proton decay

⇒ GUTs motivate proton decay searches but they do not have definitive predictions because of model dependence. (and protons can decay without GUTs as well)

6. GUTs seem to require SUSY (minimal unification)

SUSY models naturally have a new symmetry

R-parity: superpartners are odd ("charged")
SM particles are even (uncharged)

⇒ lightest superpartner is stable

if it's neutral (often it is) then it could be

WIMP dark matter. SUSY WIMP miracle → Mellisa talk.

Summary: GUTs have some aesthetically pleasing features. ☺
Predict unification of gauge couplings at 1% ☺
Yukawa unification doesn't quite want to work ☹
nothing model-independent that can be tested ⇒ we will never know if its true for sure. ☹