

Past Triumphs

Anticipations

- neutral currents \Rightarrow $W^{\pm}Z$ properties
 - radiative corrections $\Rightarrow m_t$
 - CP \Rightarrow CKM matrix, unitarity Δ
- . —
- \sim scaling \Rightarrow jet paradigm, gluons
 - running coupling \xRightarrow{LGT} hadron spectrum

Insights

- Local quantum field theory rules, OK
- Gauge symmetry
- Spontaneous symmetry breaking
- Simplicity at short distances; Analysis+Synthesis

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The Present

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Some Vertical Ascents

- The Frontier of precision:
 d , μ , B properties, ...
- Hard QCD; "backgrounds"
- Supernova explosions;
 neutron star properties
- Matter in \sim Big Bang
 conditions; RHIC

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non-locality?
 QM with $N \gg \gg 1$?
 loss of calculability?
 undecidable?
 NP?

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More broadly:

There's nowhere to

hide -

Right?

The Future

Three Sectors:

Gauge
Gravity
"Higgs"

Shortcomings 1: Gauge

- 3 groups
- 3 families
- broken families

$$\begin{pmatrix} u & u & u \\ d & d & d \end{pmatrix}_{1/6} \quad \begin{pmatrix} \bar{u} & \bar{u} & \bar{u} \\ \bar{d} & \bar{d} & \bar{d} \end{pmatrix}_{-2/3} \quad \begin{pmatrix} \bar{d} & \bar{d} & \bar{d} \end{pmatrix}_{1/3}$$

$$\begin{pmatrix} \nu \\ e \end{pmatrix}_{-1/2} \quad \bar{e}_1$$

Compelling idea for
 1st + 3rd problems: Larger
 symmetry at short distances,
 spontaneously broken.

SO(10)

	B	W	R	P	O
u	+	-	-	+	-
u	-	+	-	+	-
u	-	-	+	+	-
d	+	-	-	-	+
d	-	+	-	-	+
d	-	-	+	-	+
v	+	+	+	-	+
e	+	+	+	+	-
e ^c	-	+	+	-	-
e ^c	+	-	+	-	-
e ^c	+	+	-	+	+
d ^c	-	+	+	+	+
d ^c	+	-	+	+	+
d ^c	+	+	-	+	+
e ^e	-	-	-	+	+
v ^c	-	-	-	-	-

$$Y = \frac{1}{4} (P+O) - \frac{1}{6} (R+W+B)$$



\tilde{p} decay

(small) \rightarrow mass ✓

SUSY at LHC

If this pans out:

- more 'running' exercises
- direct access to higher symmetry
- dark matter possibilities

Challenges:

- susy breaking mechanism
- scale hierarchy
- "flavor preservation"

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Shortcomings 2: Gravity

- λ term: vacuum structure vs. gravitational universality
- Not formulation, quantization*

- Not feebleness*

$$m_p \sim e^{-c/\alpha} M_{\text{Planck}}$$

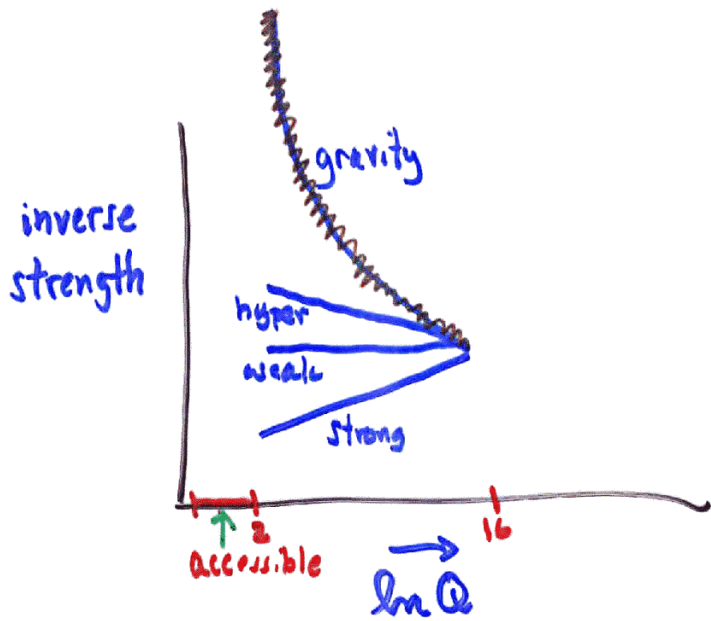
- 'Peculiarity': nonlinear target space, noncompact gauge group

* Up to inaccessible regimes

* Beyond hierarchy

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Symmetry also requires unification of couplings ...



Accurate fit requires ^{support} low-E supersymmetry!

Shortcomings 3: "Higgs"

- Where are the quanta?

radiative corrections $\Rightarrow m_H \approx 150 \text{ GeV}$
 susy likes this

- Masses and mixings

The theoretical situation is pathetic, embarrassing

Qualitative questions

$$m_e / \langle \phi \rangle \ll \ll 1 \quad (10^{-6})$$

$$m_u, m_d \quad "$$

...

One potential bright spot: axions.
 ↳ (dilaton, modulos, modulinos, quintessence, ...)

They provide:

- Explanation of θ
 $(\approx \det \text{Im} \hat{m}_a) \lll 1$
- Dark matter candidate that rationalizes
 $\rho_{\text{D.M.}} / \rho_{\text{D}} \sim 1$
 in a most interesting way.

The circle of ideas around the Standard Model offers extraordinary opportunities and challenges.