Tim Maudlin:

On the unification of physics

Two questions:

- what is unification?
- why do we want unification?

Introduction

- "most radical transformation" in last 300 yrs
- "velvet revolution" (no opposing camps, no exp. evidence)

- unification = "combination" of ≥ 2 forces

  ↳ $\exists$ math. consistency
  (i.e. no contradictions)

  $\exists$ common dynamics

  e.g. $\vec{F} = -\vec{\nabla} V$, $V \in \{V_a, V_{em}\}$

  but: V_a, V_{em} independent

  $\exists$ "law-like connection"

  e.g. Maxwell-Eqs.: duality $\vec{E} \leftrightarrow \vec{B}$

  but: ontologically different

- perfect unification

examples:

- Special relativity:

$\vec{E} \Leftrightarrow \vec{B} \Longrightarrow F_{\mu\nu}$

↑ reference frame

- general relativity:

inertia + gravity $\Rightarrow$ curved space-time

↑ $\vec{F} = m_I \ddot{\vec{x}}$ ↑ $V_G = G_N \frac{m_G M}{r}$

$m_I \equiv m_G$

Unification in modern particle physics

- Standard Model:

strong + weak + e.m. interaction

$SU(3) \otimes \boxed{SU(2) \otimes U(1)}$

common dyn. (gauge-int'n)

electro-weak

G^a_μ

$a \in \{1, \dots, 8\}$

$(W^+, W^0, W^-, B) \xrightarrow{\sin^2\Theta_W} (Z^0, A_\mu)$

independent

$\Rightarrow SU(3) \otimes EW$

$\sim V_G \otimes V_{e.m.}$

unification "at least as strong as Maxwell (true?)

- mixing $\Rightarrow$ unification ?

  Moriyasu : yes

  Georgi : no

  instead : simple group , e.g.

  GUT : $SU(5) \supset SU(3) \otimes SU(2) \otimes U(1)$

  g_{GUT} g_3 g_2 g_1

- 3 levels : 1) product group w/o mixing
  2) -"- with -"-
  3) simple group : GUT

Simplicity vs. Complexity

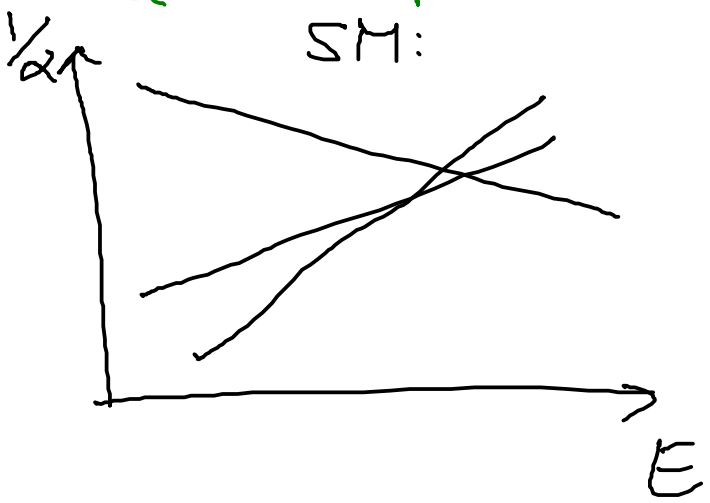
- SU(5) itself is – in some sense – simple:
  similar to QCD (= SU(3))
- needs to be broken!
  ↳ many new parameters
- need Higgs fields (ad-hoc?)

Why unification?

- exp. evidence?

  e.g. gravity : $m_I = m_G$ (empirical symmetry)

  in particle physics?



- $\sin^2\theta_W^{GUT} \approx \sin^2\theta_W^{exp}$

- aesthetic reasons?

Theory of Everything (TOE)

- SM + Gravity

problems: - "gravity is not a force"

- QFT in curved space-time ?

- $M_{GUT} \approx 10^{16}$ GeV $\ll M_{Planck} \approx 10^{19}$ GeV

Conclusions

- upper + lower bounds for unification
- motivation: emp. symmetries in particle physics?
- $SU(2) \otimes U(1)$ "more" unified than $SU(3) \otimes EW$?
- GUT
- TOE

Thoughts

- several open/controversal issues
- tight relation to hierarchy-project
  ($m^{Higgs}_{Bare} \approx m^{Higgs}_{vacuum}$)
- physicist?