

Naturalness and its Discontents

[Hopefully My Last Ever Talk On This!]

Outline

- * Naturalness as a (historically successful) guide to new physics
- * Causes for worry long before LHC
- * Experimental tests + status, @ LHC + beyond
- * Alternatives? Conservative Radicalism vs. Radical Conservatism
- * Anthropic + Multiverse; Split SUSY ← my fav. so far
- * Comments on "Conformality" approach ← my least fav. so far

Crazy Alternatives

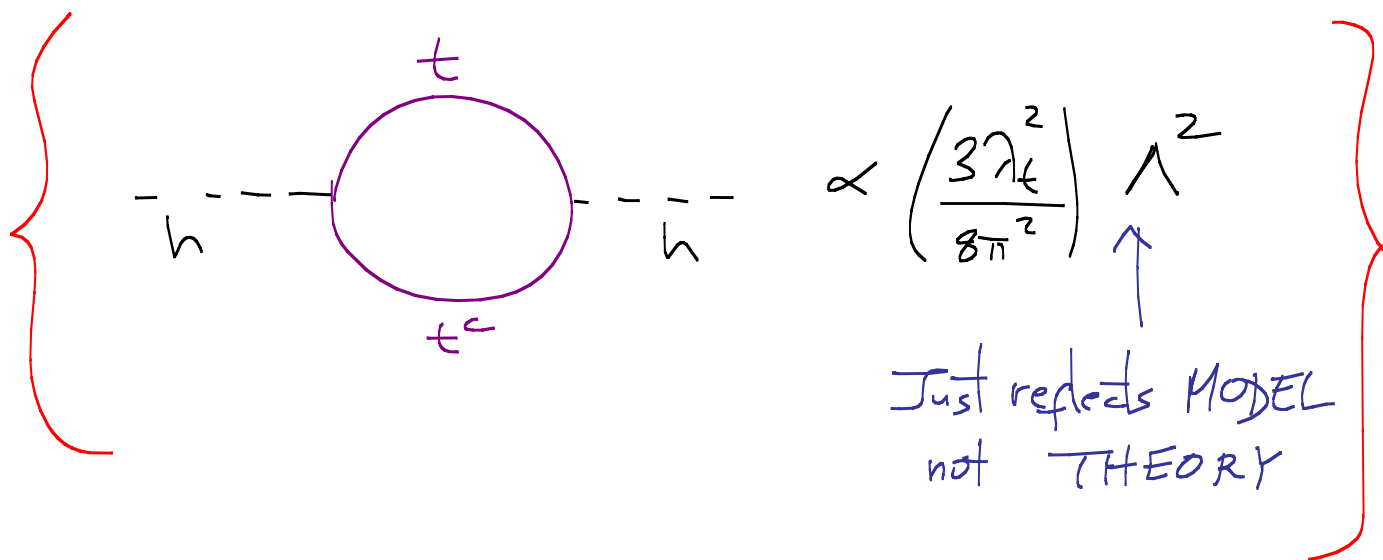
- * Self-organized criticality
- * Fat gravity + ~~Really~~ ^{much} fat gravity + exptl tests
- * Non-anthropic un-naturalness (no relevant operator principle) + expt tests
- * Cosmological SUSY breaking + expt tests
- * A small missed opportunity
- * A BIG missed opportunity, an intriguing clue, and a sharply posed theoretical challenge

Naturalness Rocks



The Standard Model is aptly named... it is a phenomenological **MODEL**, not a deep **THEORY**, of EWSB.

M_h^2 is a parameter, not predicted, but fitted by experiment!



* Higgs is SIMPLEST PARTICLE
we've ever seen

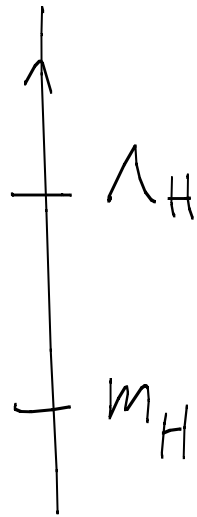
* $m_H^2 t t^\dagger H$ is SIMPLEST

PARAMETER in particle physics,
and the most relevant @ low E!

* Quest for THEORY starts here

— especially since it turns out to
be the most mysterious of all of them!

[400-yr] Reductionist Paradigm



← scale where Higgs THEORY is revealed, m_H becomes calculable

$$m_H^2 = a \Lambda_H^2 + b \left(\frac{\Lambda_H^2}{8+2} \right) \Lambda_H^2 + \dots$$

$\Lambda_H \sim m_H$: "Natural"
Complete Understanding


$\Lambda_H \gg m_H$: Needs extreme correlation
between UV + IR
physics (POSSIBLE, NEVER SEEN
BEFORE)

Borne out by all known examples,
both theoretically, as well as experimentally!

* Naturalness is not a new-fangled idea :

4 successes in 20th century

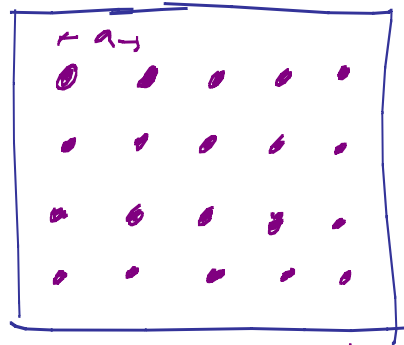
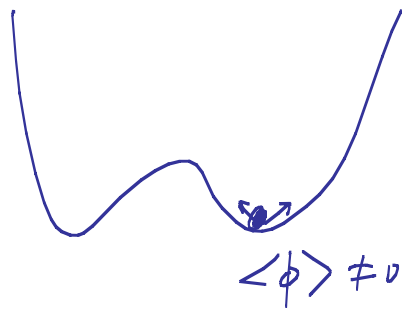
* Classical electron "hierarchy problem"

* $(\pi^+ - \pi^0)$ mass splitting 

* Δm_K

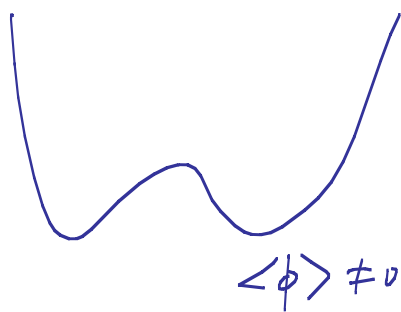
* Inferring light Higgs from precision ewk

A Famous Example

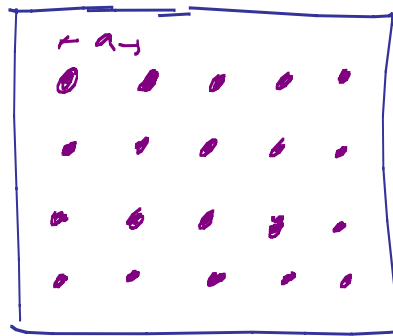


Still no understanding
of $m^2 \ll 1/a^2$!

A Famous Example



UV \rightarrow



Explanation not
in UV, but
OUTSIDE SYSTEM!

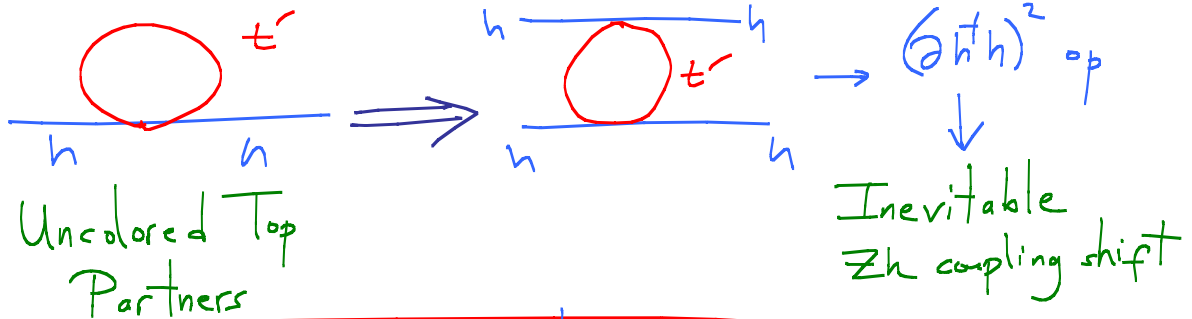
- * Here: "fine-tuning"
- * Breakdown of reductionism for this system!

"No Tuning" Well-Defined

- * $\frac{\delta x}{x} \ll 1$ [true in all historical examples]
- * Techni $S \sim 2$ vs $S \sim 1 \Rightarrow$ "natural technicolor is dead"
- * $M_{\text{stop}} \gtrsim 800 \text{ GeV} \Rightarrow$ "natural MSSM is dead"

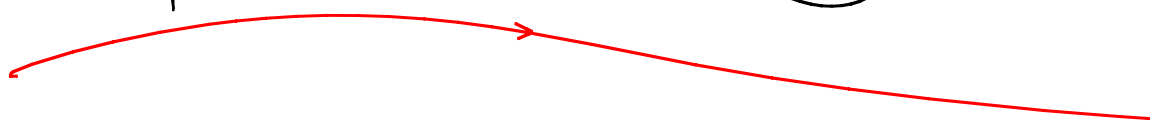
Nothing but Higgs @ LHC \Rightarrow Death of Naturalness?

NO



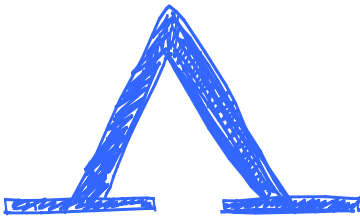
Central Argument for Higgs Factory / 100 TeV Colliders

Naturalness Sucks



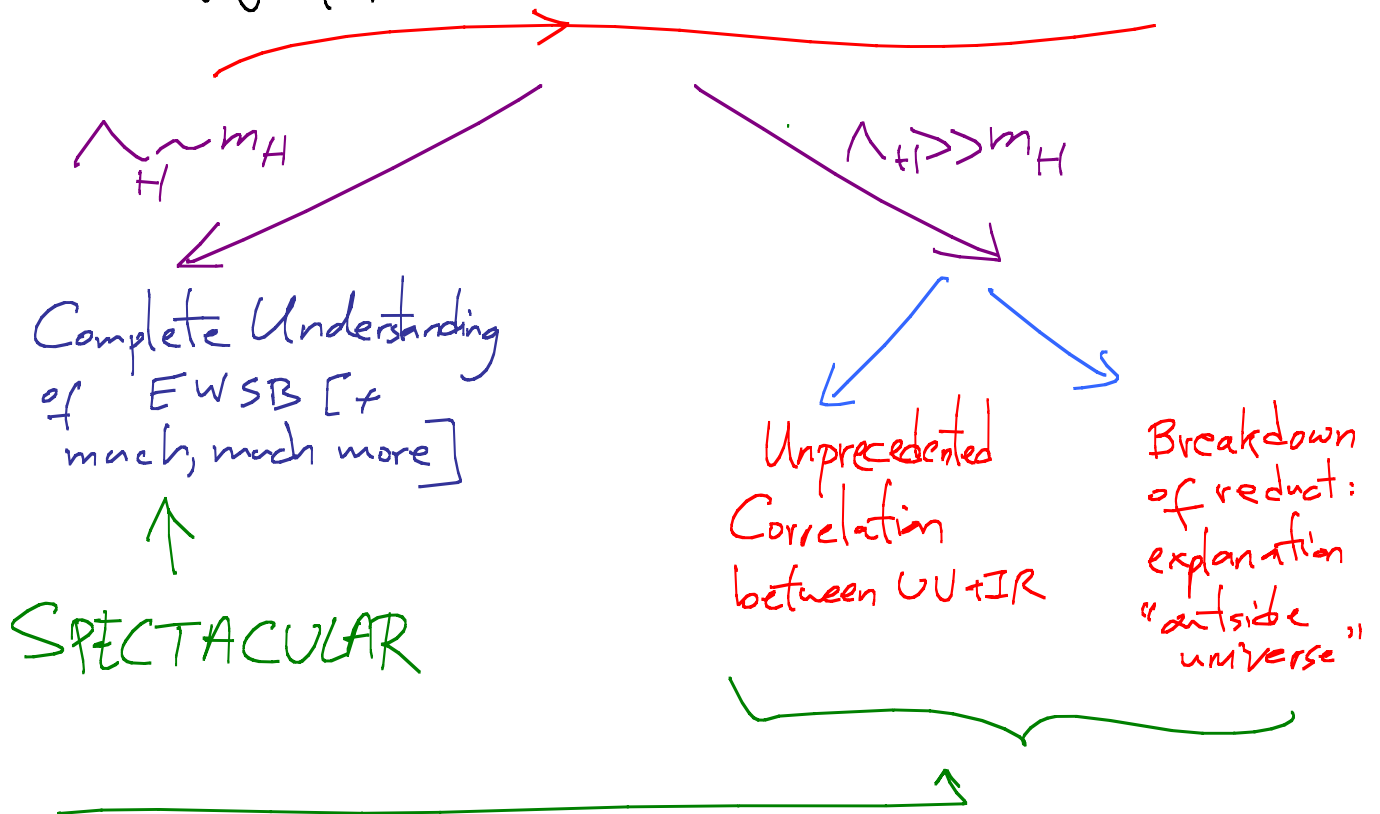
- * Remember Aristarchos!
- * $\sim 1\%$ "accidents" in nuclear physics
- * Why no FCNC's, EDM's?

*



NATURALNESS

WIN-WIN-WIN



Won't know which, but, REVOLUTIONARY either way.
Epochal change in direction of Fundamental Physics

Alternatives?



Radical Conservatism

* Copernicus

⋮

* Pauli's \checkmark

↑

ALWAYS WORKED

* String Theory

* Eternal Inflation,
Multiverse + Anthropic

Conservative Radicalism

* Ptolemy + "Epicycles"

⋮

* Bohr's Energy

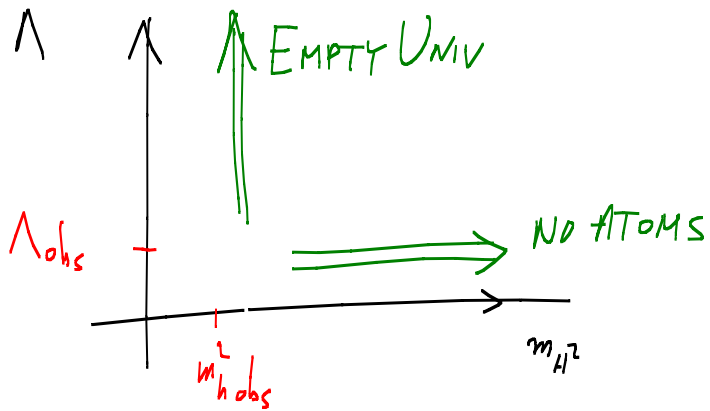
↑

NEVER WORKED

* Discrete Spacetime
(LQG, CDT, ...)

* "Fat Gravity"

* "No Λ^2 ",
No quod. div,
Conformality etc.




$$\Lambda^{1/4} \sim \frac{v^2}{M_{Pl}}$$

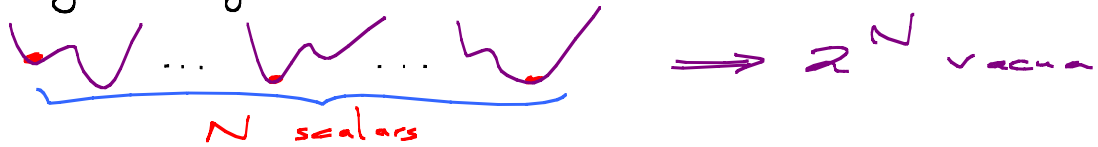
CC + Hierch. related?

"Funny Coincidences"

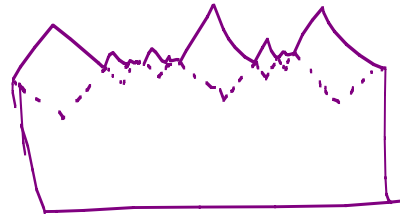
Multiverse + Anthropics



* Getting exponentially many vacua is very easy




* False vacuum inflation eternal, naively ~~populates~~ "landscape"

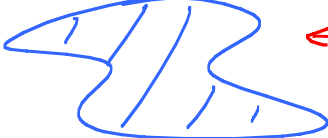


* Central Q of particle physics [vacuum] becomes tied to deepest mystery of quant cosm [$\Psi_{\text{univ}} = ?$]

* Can tie $\Lambda + m_h^2$ nicely

e.g.

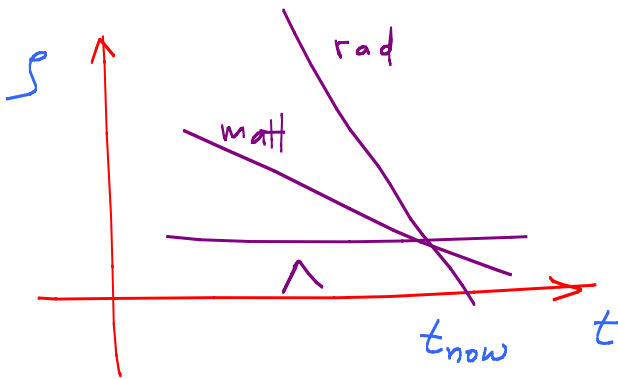

 $m_s \sim \text{TeV}$
 10^{40} vacua



← MUST tune m_h^2 to solve CC!

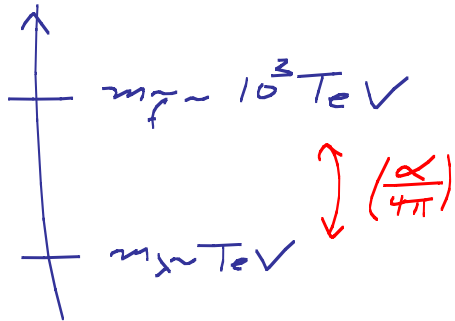
$m_s \sim 10^{10} \text{ GeV}$
 10^{140} vacua

*



If WIMP DM,
 Weinberg's argument
predicts $\Lambda^{1/4} \sim \frac{v^2}{M_{\text{pl}}}$!

Minimal Split SUSY



- * What SUSY "wants to do"
- * Unification \checkmark (improved)
- * DM \checkmark
- * All pheno. diff gone
- * $120 \text{ GeV} \lesssim m_h \lesssim 135 \text{ GeV}$, $125 \text{ GeV} \checkmark$

- * One big idea vs. model-building cleverness
- * Need some luck @ LHC, but look for \tilde{g} displaced decays