What's so little about the Little Higgs?

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The Standard Model



- consistent with all precision data
- \odot fine-tuned to 1 part in 10^{17}
- must be wrong

The Standard Model Concordance



- consistent with all precision data
- \odot fine-tuned to 1 part in 10^{17} 10^{60}
- must be wrong

Electroweak Symmetry Breaking



SUSY

Technicolor

Electroweak Break



SUSY USE



Little Higgs

Higgs is a pseudo-Goldstone boson
explicit symmetry breaking gives a potential
re-introduces quadratic divergences
if two different interactions are required to break symmetry then quadratic divergences only appear at two loops

What's So Little?

naturalness requires new physics near 1 TeV precision measurements require no new four-fermi operators below a few TeV FCNC bounds require > tens of TeV The "little hierarchy" problem is why is the Higgs light compared to ~ 10 TeV

Littlest Higgs

SU(5)->SO(5) (5²-1) - $\frac{1}{2}$ 5x4 = 14 GB's

 $SU(2)_{1} SU(2)_{2}$ $SU(2)_{1} SU(2)_{2}$ $SU(2)_{1} SU(2)_{2} SU(2)_{2}$ $U(1)_{1} SU(2)_{2} SU(2)_{2}$

Arkani-Hamed, et al., hep-ph/0206021.

Littlest Higgs

4 GB's eaten 10 GB's -> complex doublet and triplet

$$\Pi = \begin{pmatrix} 0 & \frac{H^{\dagger}}{\sqrt{2}} & \phi^{\dagger} \\ \frac{H}{\sqrt{2}} & 0 & \frac{H^{*}}{\sqrt{2}} \\ \phi & \frac{H^{T}}{\sqrt{2}} & 0 \end{pmatrix}$$

$$\mathcal{L} = \frac{f^2}{8} \mathrm{Tr} D_{\mu} \Sigma (D^{\mu} \Sigma)^{2}$$

Littlest Higgs Mass



Low Energy Effective Theory



$$M_W^2 = \frac{g^2 v^2}{4} \left(1 + \frac{(s^4 + 6s^2c^2 + c^4)v^2}{4f^2} + 4\frac{v'^2}{v^2} \right)$$



Low Energy Effective Theory

$$\frac{1}{G_F} = \sqrt{2}v^2 \left(1 + \frac{v^2}{4f^2} + 4\frac{v'^2}{v^2} \right)$$

$$\rho = 1 + \frac{5v^2}{4f^2} - 4\frac{v'^2}{v^2}$$

$$f > 4 \text{ TeV}$$

$$M_{B_H} > 0.65 \text{ TeV}$$

$$M_{W_H} > 2.7 \text{ TeV}$$

$$M_I > \sqrt{2}f > 5.6 \text{ TeV}$$

Fine Tuning

0.8% fine tuning

Tuning the Fine Tuning U(1); charges: $(\frac{n}{5}Y, 1-\frac{n}{5}Y)$



Field Guide to Models

| SU(5)/SO(5) [SU(2)xU(1)] ² | |
|--|--------------|
| SU(6)/Sp(6) [SU(2)xU(1)] ² | |
| $SO(5) \times SO(5) / SO(5)]^4$ | [SU(4)/SU(3) |

hep-ph/0207243, 0302049, 0303001, 0305302, ...

Field Guide to Models



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Comparing Little Higgs and Quintessence

doesn't address the big fine-tuning problem

clever approach to a side issue

no compelling model

Little Higgs can resolve the Little Hierarchy of Particle Physics, while the the Little Hierarchy of Cosmology (10⁶⁰) still seems Difficult

Conclusions

new way to cancel quadratic divergences
 heavy gauge boson exchange gives large corrections to EW precision observables
 to really solve the little hierarchy problem, need to explain why we live in special regions of parameter space

Going Higgsless $SU(2)_{L} \times SU(2)_{R} \times U(1)_{B-L}$



hep-ph/0308038,hep-ph/0305237