Which fine tuning arguments are fine?

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Particle physicist talks to philosopher

- I am from CERN, and you are a philosopher of physics. Say something interesting.
- Hum hum... the measurement problem?
- No!
- Quantum gravity?
- Hey, I work at 1 TeV.
- Isn't it boring?
- Well, no!

Philosophy and the LHC physics

- Symmetry
- Effective theories
- Fine tuning

  Grinbaum *Found Phys* 42:615-631 (2012), arXiv:0903.4055, 0806.4268

- Anomalies
- Theory vs. model

The concept of naturalness
Understanding naturalness

A little history
Fine tuning in models
Definitions

"Arguments from naturalness and fine tuning have dominated QFT research in a very significant way in the last 25 years." (L. Alvarez-Gaume)

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Connection with symmetry

"The naturalness criterion states that [a dimensionless and measured in units of the cut-off] parameter is allowed to be much smaller than unity only if setting it to zero increases the symmetry of the theory. If this does not happen, the theory is unnatural."
(G. 't Hooft, 1979)

- "question of aesthetics"

- "aesthetic criterion"

- "aesthetic choice"

- "the sense of 'aesthetic beauty' is a powerful guiding principle for physicists"

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Claude Perrault, 1674

". . . car la beauté n'ayant guère d'autre fondement que la fantaisie. . . on a besoin de règles. . . tellement nécessaires en toutes choses, que si la nature les refuse à quelques-uns, ainsi qu'elle a fait du langage. . . il faut que l'institution des hommes en fournisse."

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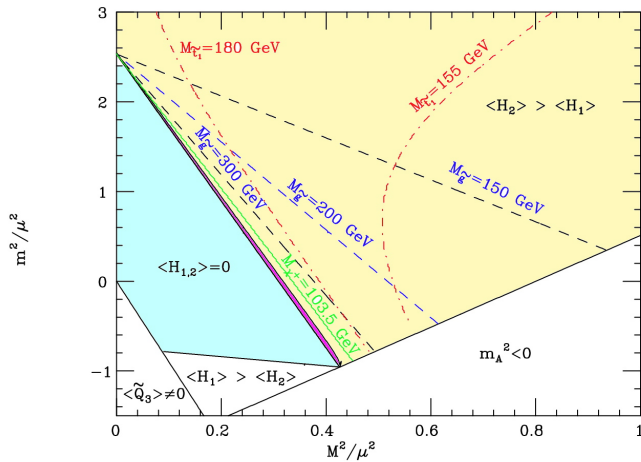A little history
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BSM models

- Supersymmetric: MSSM and the NMSSM family
- Little Higgs: inspired by the pion mass
- Extra dimensions: large or warped (AdS-CFT-inspired)
- mSUGRA family and other string-inspired
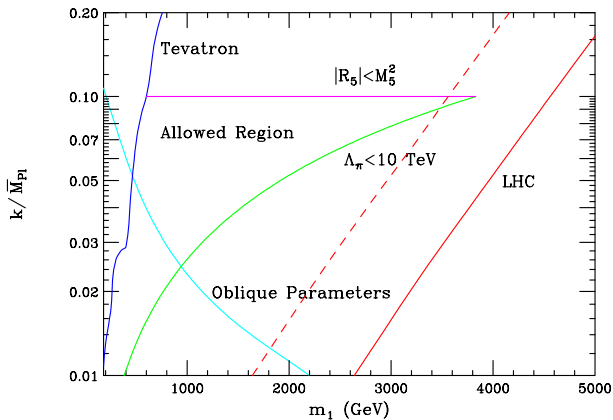- Other (technicolor, non-commutative geometry, etc.)

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Fine tuning in MSSM

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Fine tuning in a simple RS model

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Typical fine tunings

Standard Model	10^{34}
MSSM	$1 - 5\%$
NMSSM	10%
Little Higgs	10%
Simple RS	10%

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Wilson-Susskind, 1979 Observable properties of a system should be stable against minute variations of the fundamental parameters.

First measures of fine tuning: Barbieri and Giudice 1988; Ellis, Enqvist, Nanopoulos, and Zwirner 1988.

$$\Delta_{BG}(O; p_i) = \left| \frac{p_i}{O(p_i)} \frac{\partial O(p_i)}{\partial p_i} \right|.$$

Anderson-Castaño, 1995 Observable properties of a system should not be unusually unstable against minute variations of the fundamental parameters.

Problem of global sensitivity in BG. Includes an average over some 'sensible' range of parameters:

$$\Delta_{AC} = \frac{\Delta_{BG}}{\bar{\Delta}_{BG}}.$$

Athron-Miller, 2007 Fine tuning determines how rare or atypical certain physical scenarios are.

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Gedankenfrequenz
Naturalness as heuristics

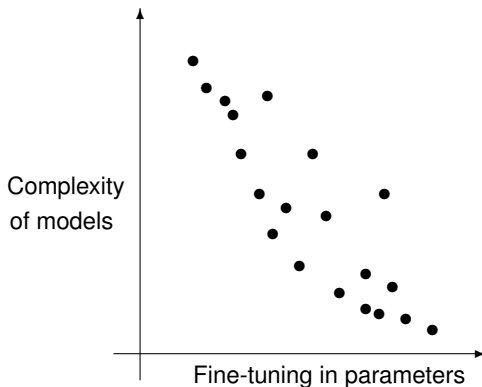## As if fine-tuning were a probability of something

- "the likelihood distribution of the theory's fundamental parameters" Anderson, Castaño

- "a chance to obtain accidental cancellations" Ciafaloni, Strumia

- "since Δ and $\Delta^{(\lambda)}$ represent independent inverse probabilities, they should be multiplied to estimate the total fine tuning $\Delta \cdot \Delta^{(\lambda)}$ in the model" Casas, Espinoza, Hidalgo

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Gedankenfrequenz

Why frequency? Because one counts the number of particular
occurrences in a class of imaginary untestable
numerical scenarios. Frequency is *stranger than
hypothetical*.

Why Bayesian? Because the probability is our bet on the future
state of knowledge and because the range of
parameters shows our "confidence limit". We do
not know the value which we believe to be known
in future. It makes no sense to assign a probability
to the parameter after it has been measured.

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Schematic graph of fine tuning versus model complexity in the space of models beyond SM

Complexity of models

Fine-tuning in parameters

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Fine tuning warrants a sociology of BSM models

1. Experimental findings of the last 25 years have not been conclusive. One cannot tell the true from the false models on the basis of experimental data.

2. Socio-historic dynamics of physical theory is defined by naturalness, which functions as a criterion of *mathematical* plausibility.

3. Popper's falsification has mutated into an abstract probabilistic version.

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Beauty vs. simplicity

Quine Simplicity, economy and naturalness. . . contribute
to the molding of scientific theories generally.

Dirac The research worker, in his efforts to express the
laws of Nature in mathematical form, should strive
mainly for mathematical beauty. He should still
take simplicity into consideration in a subordinate
way to beauty. . . It often happens that the
requirements of simplicity and beauty are the
same, but when they clash the latter must take
precedence.