

Naturalness and the Forward-Looking Justification of Scientific Principles

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Question:

Why was the naturalness principle employed so heavily over the last 40 years, and how is the current loss of relevance to be explained?

My Proposal:

Naturalness received **forward-looking justification**, through coherence with theories of BSM physics that were taken to be promising but unconfirmed.

The shift in attitude is a reaction to experimental constraints on leading BSM proposals that were formulated in response to the naturalness principle.

- **Technicolor**

- avoid elementary scalar by dynamical mass production for W and Z .
- but: problems with Higgs lighter than 1 TeV and width less than a few GeV.

- **Low Energy Supersymmetry**

- posits symmetry between integral and half-integral spins; mass of elementary scalar would be protected by this symmetry.
- but: e.g. MSSM requires fine tuning of 1 part in 10^4 .

- **Extra Dimensions**

- bring fundamental scale close to the scale of electroweak breaking by positing extra dimensions.
- but: strong experimental constraints on the viability of this approach.

Giudice on naturalness:

- **2008**: violation of naturalness "would signal a breakdown of the philosophy underlying the effective-theory approach."
- **2013**: naturalness is a "very useful tool for physicists to make progress along the path towards the inner layers of matter," however, Giudice also states that the "naturalness principle is certainly not a *necessary* condition, indispensable for the internal consistency of [effective field] theory."
- **2018**: "dawn of the post-naturalness era"; naturalness will still play a role, but new guiding principles have to be found.

Further evidence from empirical studies conducted by Mättig and Stöltzner (2019).

Need to explain

- 1 the central role that the naturalness principle played as a motivation for BSM proposals,
- 2 the perceived loss of significance of naturalness considerations as a result of the absence of new physics

If proponents of naturalness explain (1), they have difficulties explaining (2).

If opponents of naturalness explain (2), they have difficulties explaining (1).

Principles are justified by the fact that they give rise to promising theories.

Naturalness gave rise to theories that were *perceived to be* promising but unconfirmed, and were taken to be experience FLJ.

These theories are *perceived to be* less promising now, which undermines FLJ.

1. Support through potential coherence

- Coherence with technicolor, extra dimensions: theories that are natural *by construction*
- Unexpected coherence with SUSY

Now: options for coherence with naturalness principle are more limited.

2. Relevance through potential solution

- Problem inflation by potential solution: the naturalness problem gains relevance through potential solutions.

Now: Relevance is deflated since solutions loose promise: 'unnatural' solutions or multiverse scenarios become serious contenders.

What is the function of forward-looking justification?

What is the relation to concepts of research heuristics and pursuit worthiness?

Are there other instances of forward-looking justification?