Non-Empirical Confirmation in Cosmology

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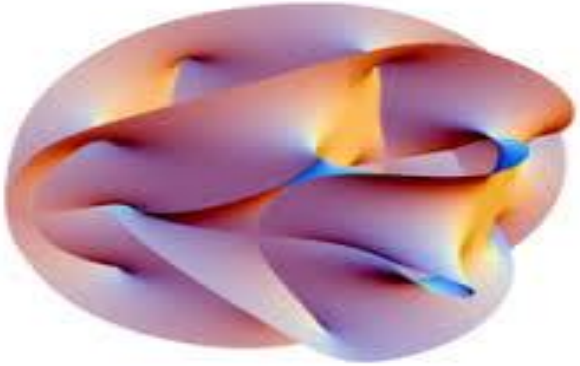
The Canonical View on Science

- Scientific Theories make empirical predictions.
- By confirming a theory's core predictions, one can establish it as empirically viable.
- As long as its core predictions remain empirically unconfirmed, the theory remains a speculation.

A Problem for Fundamental Physics Today



- No theory of the last 45 years in high energy physics and cosmology has found (conclusive) empirical confirmation up to now.
- But some of them are strongly trusted by their exponents:
  string theory, SUSY, cosmic inflation, multiverse …
- This general situation is likely to stay with us for quite some time.

Can the current situation in fundamental physics be understood more adequately based on a broader perspective on theory confirmation?

The conceptual framework

A Bayesian view on confirmation: Evidence E confirms Theory H iff

$$P(T|E) > P(T)$$

T: H is *viable* in a given regime: it agrees with all the data that can in principle be collected in that regime.

- Talking about viability rather than truth safeguards that predictively empty theories are not up for confirmation.

What we are interested in is: which kind of evidence can legitimately generate substantial trust in a theory's viability?

- This is less than establishing P=1 or P nearly 1.
- But it is more than just confirmation in a Bayesian sense (which could also be marginal).

The Suggestion: Distinguish Two Kinds of Confirmation

The claim: substantial trust in a theory can be generated based on two lines of reasoning.

- Empirical theory confirmation: based on empirical data predicted by the theory.
- Non-empirical theory confirmation (NEC) (Dawid 2013): based on observations beyond the theory's intended domain.

Non-Empirical Confirmation

- NEC is *not* a general term for all reasons for trusting a theory that are not based on empirical confirmation.
- Rather, it specifies a class of evidence that is claimed to be capable of generating *substantial* confirmation.

Other *non-empirical* ways of assessing a theory would include: pointing at simplicity, elegance, beauty, gut feeling,…

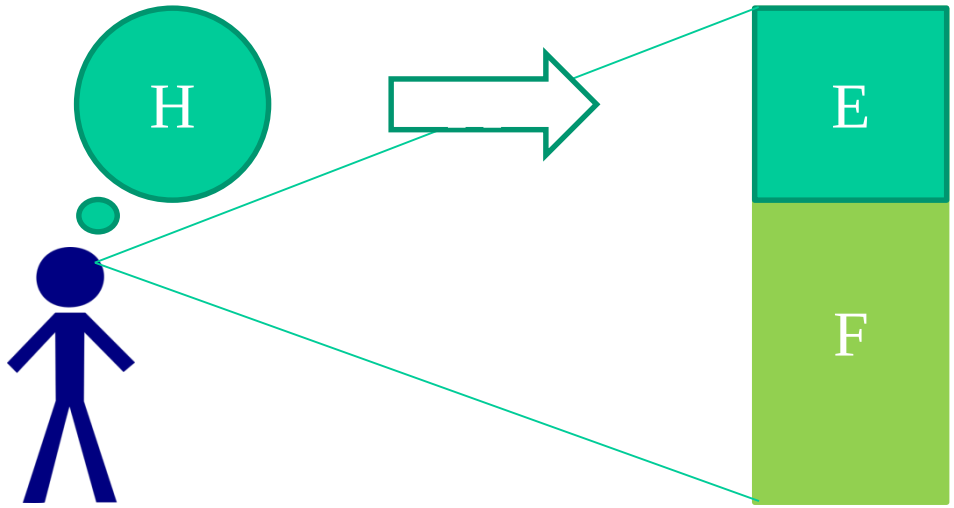
NEC differs form them in at least two ways:

- ➢ It relies on a conceptual framework that can be more easily operationalized that concepts like simplicity, elegance, or beauty.
- ➢ It is not based on pointing at a quality of the theory but relies on observations about the world. (though not of the kind gathered to test the given theory)

„Non-empirical“, but based on observations

- We look for arguments of theory assessment that rely on observations F about the world.

- They are “non-empirical”: not in the theory’s intended domain.
- But they reach out beyond scientist and theory.



3 Non-Empirical Arguments (NEA)

Three types of meta-level observations F provide the basis for the main arguments of non-empirical assessment:

1. "No Alternatives" Argument (NAA): Despite extensive search scientists haven't found an alternative theory.

2. Meta-inductive Argument (MIA): Other comparable theories in the research field were empirically successful later on.

3. "Unexpected-Explanation" Argument (UEA): the Theory explains something without having been developed to that end.

- MIA is essential and relies on empirical confirmation someplace else in the research field.

=> NEA is never "post-empirical".

- All three arguments rely on an observation.
- All three observations *confirm* the hypothesis that there are few - or no - possible alternatives to the theory at hand.

How does NEA work?

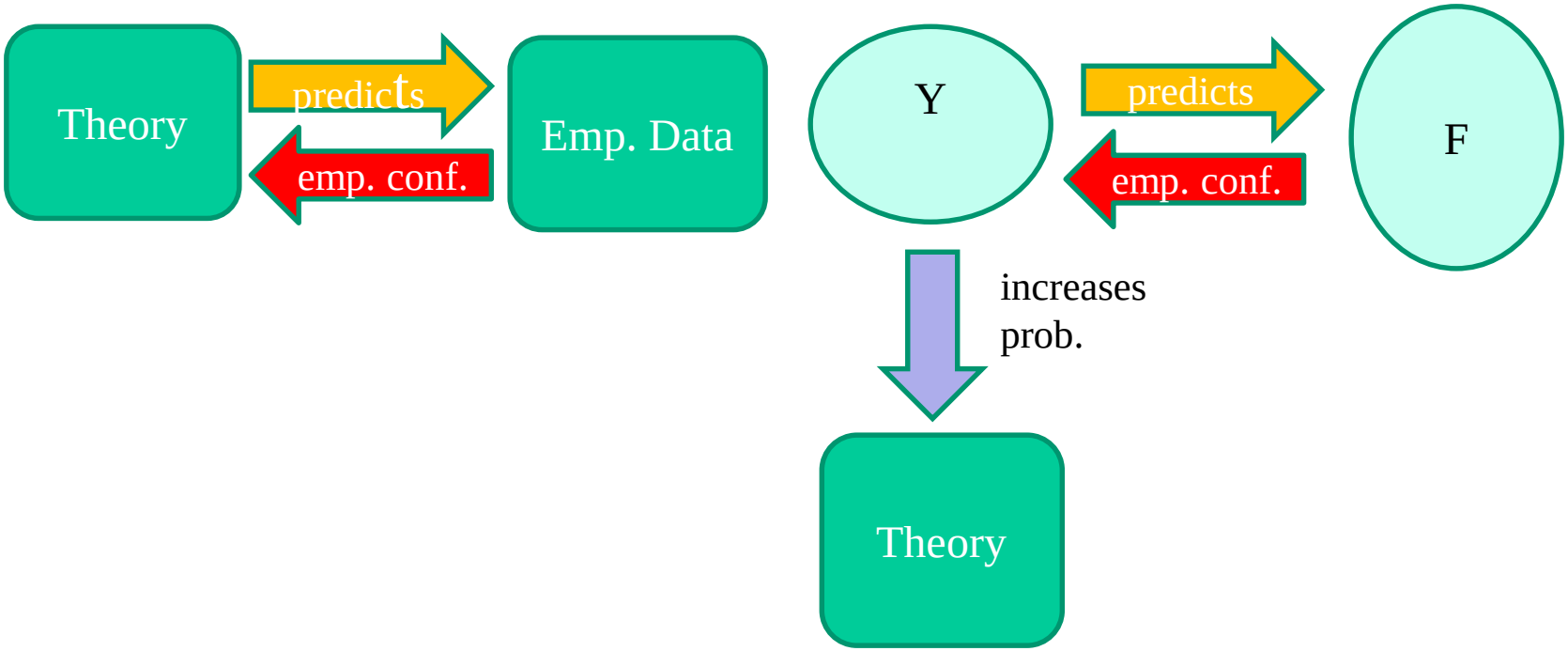
Empirical confirmation

- Empirical data E

Non-empirical assessment

- meta-level observations F
- A meta-level hypothesis Y

(on limitations to underdet.)



The role of NEA in physics

- The use of NEA is not at all new. It has always been crucial for establishing that the predictions of an empirically well confirmed theory can be trusted:
  - ➢ Trust in a theory's predictions must assume that there are few if any alternative theories implying different predictions.

- But
  - the scarcity of empirical data in many fields
  - and the rigidity of consistency arguments in fundamental theory building

  have made a new question very relevant:
  - ❖ How strong can NEA for a given theory be in the absence of empirical confirmation?

⇒ NEC: substantial confirmation of a theory based on NEA in the absence of empirical confirmation.

Suggestion: Distinguish Two Kinds of Confirmation

NEC has so far been discussed by physicists mainly in 2 contexts.

It is discussed in quite different ways in each case:

- String theory: exponents of ST who subscribe to NEC vs. critics of both.
- Cosmic inflation: Critics of inflation see NEC where exponents don't.

Claim of this talk: NEC is important in inflation even though there is empirical data.

Nonempirical Confirmation and Cosmology:

- In contemporary cosmology one finds:
  - Substantial empirical evidence.
  - But no conclusive evidence for fundamental theories.

Thus it is an interesting context for understanding the difference between:

– NEA as a supporting element of empirical confirmation

and

– NEC as an independent mode of confirmation.

I: A case of empirical confirmation: The Discovery of a Cosmological Constant

- In 1998, Perlmutter et al. and Riess et al. announced redshift data from distant supernovae that indicated an accelerating expansion of the universe.

  This could be explained by a positive cosmological constant Λ.
- The data itself was clearly significant and unassaillable.
- The issue was: are there possible alternative explanations?
  - Dust
  - Tampering with gravity
  - ...

- It took several years before $\Lambda \neq 0$ was (nearly) generally accepted.
- Some doubts remain until today.

I: A case of empirical confirmation: The Discovery of a Cosmological Constant

- The evidence for $\Lambda \neq 0$ is a clear case of empirical confirmation.
- But the generation of trust in the hypothesis relies on NEA:
  - NAA: Inference from exclusion of alternatives to “no alternatives”.
  - MIA: Gauging the significance of NAA by considering past cases of evidential support in physics that was considered reliable due to a NAA.
  - UEA: e.g. the consistent dating of very old galaxies.

- The NEA deployed, however, is dependent on the empirical evidence:
  - No NAA in the absence of the supernovae data.

$\Rightarrow$ NEA plays a strictly supportive role within empirical confirmation.

! But: empirical confirmation of the $\Lambda \neq 0$ hypothesis would be unconvincing if NEA were no strong argument!

II: Non-empirical confirmation? Cosmic Inflation

- Some general characteristics of the universe remained unexplained by „ old standard cosmology“.
  - Isotropy of space
  - Flatness of the universe
- In 1981, Alan Guth proposed an early exponential expansion phase of the universe that would
  - Imply that the observable universe is causally connected => isotropy
  - Generate a near flat universe.
- Today, there is substantial novel empirical support for implications of typical inflation models based on CMB.
  - Density fluctuations are nearly scale invariant.
  - in thermal equilibrium.
  - nearly Gaussian.

II: Non-empirical confirmation?
Cosmic Inflation

To what degree do these data empirically confirm the theory?

One core issue:

- Data support typical solutions of inflation.
  - But the physical mechanism of inflation has not been specified yet.
  - There is a huge number of models and probably many more that are so far unconceived.

  ? What does „typical“ mean?

This disconnects testing a model from testing the theory.

$\Rightarrow$ It has been argued that, as it stands, inflation is not an empirically testable hypothesis at all. (Steinhardt)

II: Non-empirical confirmation? Cosmic Inflation

- But the question can be asked whether there is another theory than inflation that can explain the data at all.
- If not (which is disputed, to be sure), NAA can be used even in the absence of a strong prediction at the theory level.
- While empirical testing remains at the level of models, NAA(+MIA) works at the theory level.

$\Rightarrow$ The data serves rather as a framework for NEC type reasoning than as actual empirical confirmation.

$\Rightarrow$ NEA-supported empirical confirmation „slides“ towards genuine NEC.

Claim: This element of „quasi NEC“-reasoning plays a substantial role in generating trust in inflation.

II: Non-empirical confirmation? Cosmic Inflation

How about UEA?

- UEA would be very helpful.
- There is one striking example of UEA.
  - Anthropic explanation of the finetuned Λ relies on eternal inflation.
- Anthropic reasoning is itself contested, however.

Conclusion

- NEA has always been an integral though somewhat underrated element of confirmation.
- In the form of NEC it can generate trust in a theory in the absence of empirical confirmation.
- Cosmology demonstrates the „slippery slope“ that leads from NEA to genuine NEC.
- The two described cases show how close NEC is to supportive reasoning in empirical confirmation.