

Level Up Your Philosophy of Science



A crash course in PhilSci for
astrophysicists

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*Let's say a philosophy PhD is 20, most scientists are 0, and objectivity is an illusion

What is Philosophy?



- ❧ Philosophy is a practice based on using reason to explore various issues.
- ❧ Physics attracts a bunch of Philosophy Haters (Weinberg, Hawking, Krauss, ...) who don't understand that *philosophy is not science*. (They are making a *category mistake*.)
- ❧ The purpose of the philosophy of science is not to make or contribute to scientific discoveries but to question all aspects of science's process, context, tools, subjects of study, assumptions, etc. *Scientists would benefit from a basic knowledge of philosophy just as they do statistics and computer science.*

Phil Sci 101



The Demarcation Problem
Scientific Explanation
Scientific Realism

Phil Sci 101



The Demarcation Problem - What is Science?
Scientific Explanation - What does Science Do?
Scientific Realism - What is Science About?

Some Definitions



- ❧ **Epistemology:** the study of knowledge or justified belief
 - ❧ What constitutes knowledge and what are its sources?

- ❧ **Ontology:** concerns the nature of being, existence, reality
 - ❧ What kinds of things exist?

- ❧ **Semantics:** concerns meaning and representation
 - ❧ What do things (models, theories, sentences) mean?

Watch this space for reference URLs!

The Demarcation Problem



What distinguishes between science and non-science?

⌘ Logical Positivism

Lvl. 0

- ⌘ Verifiability: a scientific statement is only meaningful if we have some means of verifying its truth
- ⌘ **Problems:** confirmation paradox; problem of induction

⌘ Falsificationism (Popper)

Lvl. 1

- ⌘ Scientific statements must be capable of conflicting with possible or conceivable observations
- ⌘ **Problems:** not sufficient; not practical

The Demarcation Problem



Lvl. 2 ☞ Puzzle-solving and Paradigms (Kuhn)

☞ Falsification only applies to rare instances when whole theory is at stake (“revolutionary science”); normal science solves puzzles within accepted paradigm

Lvl. a lot ☞ Modern approaches:

☞ Laudan: demarcation is impossible, needs both *necessary* and *sufficient* conditions

Logic: +1 level

☞ McIntyre, “The Scientific Attitude”: we can nevertheless identify necessary, if not sufficient, conditions to rule out what is not science

Scientific Underdetermination

Level Up! No longer a noob!



- ⌘ Duhem-Quine thesis: scientific knowledge is the result of a complex web of interconnected beliefs
 - ⌘ **Holistic Underdetermination:** experiments don't test just the focal theories but a web of auxiliary hypotheses including assumptions of the instrument functionality, data analysis, corollary theories, etc.
 - ⌘ *Ex: faster-than-light neutrinos! Neptune vs. Vulcan!*
 - ⌘ **Contrastive Underdetermination:** evidence that supports a theory may also support an alternative theory (which may or may not be known)

Scientific Explanation



What counts as scientific explanation?

Latin: +1 level

∞ Deductive-Nomological model: *Explanandum* phenomenon is explained by *explanans*

1. *Explanandum* must logically follow from *explanans*, which must be true
2. *Explanans* must contain at least one “law of nature”

∞ Statistical Relevance model

∞ Attribute *C* is statistically relevant explanation of *B* only if it changes the probability of *B* occurring given population *A*: $P(B|A,C) \neq P(B|A)$. *Anthropic cosmological arguments: -1 level*

∞ *And many other models...*

Scientific Realism



- ❧ Ontological/metaphysical: mind-independence of world investigated by sciences
 - ❧ **Anti-realism**: As distinct from “world in itself”, world investigated by sciences depends on e.g. theoretical assumptions and perceptual training

- ❧ Semantic: theories are literal (at face-value) descriptions of nature
 - ❧ **Anti-realism**: Claims about unobservable things have no literal meaning (*Instrumentalism*)

Scientific Realism



- ❧ Epistemic: theoretical claims constitute knowledge of the world
 - ❧ **Anti-realism**: Past theories have been shown to be false, so it is unreasonable to believe that current theories are true (*Pessimistic Meta-Induction*) Fancy name:
+1 level
- ❧ The *Miracle argument* for realism (Putnam)
 - ❧ Realism is the only position that does not make a miracle of the predictive success of science

Modern Topics in the Philosophy of Science



Observation & Experiment
Models & Measurement
Social and Feminist Epistemology

Observation/Experiment



- ❧ Data vs. Phenomena (Bogen & Woodward 1988)
 - ❧ Data are “idiosyncratic to particular experimental contexts”, while phenomena have “stable, repeatable characteristics”
 - ❧ Theories must explain phenomena, not data
- ❧ Experimental validity (Campbell & Stanley 1963)
 - ❧ **Internal:** experiment captures a causal relationship (CR)
 - ❧ **Construct:** the CR being tested is the correct one
 - ❧ **External:** results are generalizable to phenomena
 - ❧ *Applies also to numerical simulations?*

Later than 1950:
+1 level

Models



- ∞ **Semantics**: What is the representational function that models perform?
 - ∞ Models of **phenomena**: e.g. Bohr atom, double-helix DNA
 - ∞ Models of **data**: e.g. after processes of data reduction, curve fitting, filtering, etc. → *cleaned images, object catalogs*
 - ∞ Models of **theory**: apply laws and axioms to a system

- ∞ **Epistemology**: How do we learn with models?
 - ∞ Learn about the model by building and manipulating
 - ∞ Mathematical → analytic solutions/computer simulation
 - ∞ How to transfer knowledge about the *model* to knowledge about the *target system*? → $\bar{\setminus} _ (\sphericalangle) _ / \bar{\setminus}$ **Admit uncertainty: +1 level**

Measurement



What do scientists *do* when they make measurements?

- ⌘ Many accounts, not necessarily inconsistent:
 - ⌘ **Mathematical**: relate qualitative to quantitative
 - ⌘ **Operationalist**: operations that shape meaning
 - ⌘ **Realist**: estimate mind-independent properties/relations
 - ⌘ **Information-theoretic**: gather & interpret information
 - ⌘ **Model-based**: coherent assignment of values to parameters

- ⌘ **Epistemology**: measurement is *theory-laden* Level Up!
 - ⌘ Inferences from instrument readings to measurement results are nontrivial and depend on theoretical & statistical assumptions. *Ex: all of astronomical image processing!*

Epistemology of Science



How is process of knowledge-gathering framed by society, individuals, and culture?

Level Up for even asking!

- ⌘ In large collaborations, when individuals don't fully understand evidence, how are results "known"? (*How does LIGO work? Where/how is this knowledge situated?*)
- ⌘ How do goals of individual scientists (credit) interact with goals of community (true theories)? (*sometimes poorly...*)
- ⌘ In what ways does social organization of a community have bearing on the knowledge produced by that community? *Ex: harassment and bullying, hierarchies, funding allocation, ...*

Epistemology of Science



How does/ought gender influence our conceptions of knowledge, the knowing subject, & practices of inquiry?

☞ Situated Knowers and Situated Knowledge

☞ Knowing in relation to: embodiment; first- vs. third-person access; emotions, interests, values; skills; cognitive styles; worldviews; relations to others...

☞ Sexist/androcentric, racist/white-centered, etc. biases can lead to error or unjustified conclusions

☞ Non-referring concepts (e.g. biological “race”); violation of valid methodological principles; belief despite lack of evidence; ...

Epistemology of Science



- ⌘ (Problematic?) conceptions of objectivity:
 - ⌘ **Subject/object dichotomy** – separate knowers and known
 - ⌘ **Aperspectivity** – the “view from nowhere”
 - ⌘ **Detachment** – maintain emotional distance
 - ⌘ **Value-neutrality** – w.r.t. moral, social, political values
 - ⌘ **Control** – experimental manipulation to produce regularities
 - ⌘ **External guidance** – beliefs guided only by nature of the object

- ⌘ General critique: these conceptions generate *partial* accounts of the world, misrepresented as complete and universal

Thank You!



Further reading: Stanford Encyclopedia of Philosophy
<http://plato.stanford.edu>

What are modern philosophers of astrophysics up to?



- ❧ “Modeling Black Hole Coalescence: Numerical Relativity and Ligo” - Jamee Elder
- ❧ “Using Data Models and Simulations in Testing Supernova Cosmology” - Genco Guralp
- ❧ “Data Reduction in Astronomical Interferometry - Data Models & Observational Underdetermination” - Marja Seidel
- ❧ “Simulationist’s Regress in Laboratory Astrophysics” - Helen Meskhidze
- ❧ “Simplicity and Unification in Cosmological Model Selection” - Yann Benétreau-Dupin
- ❧ “Model Independence in the Search for Dark Energy” - Casey McCoy