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The Theory/Experiment Interface of the Observation of Black Holes

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Do Black Holes Exist?

- mathematical descriptions
- physical properties
- empirical consequences
- measurements of consequences

The Problem

When do results of a measurement give good reasons that we have found a special physical object?

Special case:

When do results of measurements of stellar orbits, special X-ray emissions, and near infrared emissions from the location of the radio source Sagittarius A give good reasons that we have found a supermassive black hole?*

Good empirical reasons for the existence of Black Holes?

What scientist do:

Eckart, A., Kiefer, C., Britzen, S., et al.

The Milky Way's Supermassive Black Hole: How good a case is it? Foundations of Physics 47 (2017) 553-624

What philosophers think about it:

Can philosophy of science supply some general criteria for an answer?

> There is no concluding answer, but a variety of proposals for solving similar problems

What philosophers think about it:

Typical problem: When does some evidence confirm a general theory?

Philosophy of science has its own tradition.

Starting with Logical Positivism (empiricism & modern logic)

- elementary applications of logic to scientific sentences
- later on: studying more realistic case studies

Overwiew

1. Theories and facts in logical empiricism
2. Deductive and inductive approaches to a theory of confirmation
3. A more complex picture of the theory/experiment interface
4. A new methodological interest in experiments
5. Arguing for the existence of physical objects
6. Proposals for partial solutions
7. Philosophy of science and reflective equilibrium

1. Theories and facts in logical empiricism

Movement of philosophers in 1920s, 1930s (Vienna, Berlin) England, later on USA

linguistic turn

modern logic

empiricism

Meaningful propositions must either be analytic or empirically verifiable

mathematics: analytic truth

sciences: based on logical inferences from simple *'protocol sentences'* grounded on observable facts *(empirical and theoretical language)*

metaphysics: not meaningful

Generalized sentences can not be verified:

Two components:

(1) Basic propositions (directly and strictly verifiable, incorrigible).

(2) All other propositions can indirectly verified by reference to the empirical basis (1).

empiristic tradition in epistemology

fundamentalism or coherentism (empiristic or rationalistic)

R. Carnap: ***confirmation*** (inductive logic)

Justifying general propositions (laws) by special instances.

Questions of existence of special physical objects are similar to questions of justification of general theories.

2. Deductive and Inductive Approaches to a Theory of Confirmation

General propositions (“All ravens are black.”) can not be proven by a finite number of observations.

We need more tools than plain logical entailment.

Reasoning from evidence is necessarily fallible.

General idea:

Evidence (observations, data, reports of the result of experiments (premises)) can affect the credibility of hypotheses.

Confirmation by instances

Hypothetico-deductivism

Evidence ***e*** confirms a hypothesis ***h*** in case the latter is able to entail ***e*** (with the help of suitable auxiliary hypotheses and assumptions).

Problems: varying degrees of credibility

Popper: Falsificationism

Sceptical position: Theories can not be confirmed, but they can be falsified (evolutionary process: surviving theories are "nearer to the truth").

Underdetermination

Given any theory about unobservables which fits observable facts there will be other incompatible theories which fit the same fact.

Duhem-Quine-Problem: (h & a) → e

→ We should be able to say more about the degree to which a given body of evidence supports a given theory.

Instead of purely logical relations:

degrees of belief, credibility of proposition
subjective (epistemic) probabilities

Bayesian confirmation theory

- # formal apparatus for inductive logic
- # laws of probability are coherence constraints on rational degrees of belief (degrees of confidence)
- # part of a general conception for belief, inference and behaviour

Unconditional probabilities P(b) as primitives

Conditional probabilities: $P(b|a) = P(b\&a)/P(a)$

Start with $P_i(h)$ ('prior')

$P_f(h) = P_i(h|e)$

$P_f(h) = (P_i(e|h)\,(P_i(h)) \,/\, P_i(e)$ *Bayes Theorem*

Bayesian confirmation theory

$P_f(h) = (P_i (e|h) (P_i(h)) / P_i(e)$ Bayes Theorem

Dynamics of belief revision

Example: Confirmation effect of ***surprising evidence***

e is much more expected if it were known that h were true

3. **A More Complex Picture of the Theory/ Experiment Interface**

Logical empiricism: just experimental reports

Mario Bunge, Philosophy of Physics, Dordrecht 1973, chpt. 10

" …data are anything but given: they are produced and interpreted with the help of theories."

" … most theories do not concern observations and measurements, let alone acts of perception, but things or rather idealised models of them."

"… testable propositions seldom if ever follow from the assumptions of a single theory but, rather, are usually entailed by the theory in conjunction with additional assumptions and with bits of information other than those serving to check the theory."

…. Mario Bunge, Philosophy of Physics

History of science:

“ … the history of science abounds in examples of theories that have been upheld in the face of adverse empirical evidence –

- and rightly so, for the data proved wrong in the end.”

Nonempirical tests:

The theory “must be well built, it must not go against the grain of justified scientific beliefs, and it must not postulate items that are either metaphysically objectionable (such as an electron’s ability to make decisions) …”

Consistency, coherence

… Mario Bunge: Philosophy of Physics

Observation:

"Scientific observation, unlike the observations of babies and empiricist philosophy, is permeated by hypotheses and expectations, some explicit, most tacit."

(even ordinary observation is determined jointly by sensation and ideation)

Empirical evidence is neither purely empirical nor conclusive.

Duhem-Quine

4. A New Methodological interest in experiments

Logical empiricism:

Experimental process was set aside, only the final product has been considered: experimental reports.

New interest in experiments:

Franklin, Galison, Hacking (1983)

Experiments provide us with knowledge of the physical world, experiments provide the evidence.

describing experiments in detail

emphasizing human action and causal interaction

Allan Franklin: **What makes a good experiment?**
Pittsburgh 2016 (Pittsburgh University Press)

Experiments can be good in many ways:
conceptually good, methodologically, technically, pedagogically important

There is no simple set of criteria for ranking or evaluating good experiments.

Part III:
Evidence for entities *(neutrino, Higgs boson)*

5. Arguing for the Existence of Physical Objects

When we are justified in believing in the existence of a special type of physical objects?

W. Sellars (1962): “to have good reasons for holding a theory is ipso facto to have good reasons for holding that the entities postulated by the theory exist”

objects as “necessary” parts of theories (Quine)

(fields in electromagnetism)

? special entities, that might exist (additional planet)

(space-time singularity: limit of the domain of applicability of general relativity?)

… W.V.O. Quine

There is no special (philosophical) way to ontology:

> “Ontological questions … are on par with questions of natural science”
> “We do not learn first what to talk about an then what to say about it.”

Context of theories: Direct experience is not necessary.

> “We posit molecules, and eventually electrons, even though these are not given to direct experience, merely because they contribute to an overall system which is simpler as whole than its known alternatives.”

… *W.V.O. Quine*

“Ontic decisions”: similar criteria as for theories:

Simplicity, scope (unification), fruitfulness

“How do we decide, apropos of the real world, what things there *are*? Ultimately, I think, by considerations of simplicity plus pragmatic guess as to how the overall system will continue to work in connection with experience.”

Holism

… *W.V.O. Quine*

> “The empirical relevance of the notion of molecules and electrons is indirect, and exists only by the virtue of the links with experience which exist at other points of the system. Actually I expect that gables and sheep are, in the last analysis, on much the same footing as molecules and electrons.”
>
> “In whatever sense the molecules in my desk are unreal and a figment of the imagination of the scientist, in that sense the desk itself is unreal and a figment of the imagination of the race.”

Continuum in epistemic access to objects, but not in the meaning of ‘existence’.

W. Sellars (1962):

> "to have good reasons for holding a theory is ipso facto to have good reasons for holding that the entities postulated by the theory exist"

Cartwright (1983)/ Hacking (1983): **manipulability of an entity as criterion for belief in existence** → trouble with astrophysics

In contrast Franklin *("Experiment in physics", Stanford Encyclopedia of Philosophy, Appendix 7)*

> "I will argue that experimenting *on* entities and measuring their properties can also provide ground for belief in their existence."

Status of laws?

J.J. Thomson and the electrons:

> “As the cathode rays carry a charge of negative electricity, are deflected by an electrostatic force as if they were negatively electrified, and are acted on by magnetic force in just the way in which this force would act on a negatively electrified body moving along the path of these rays, I can see no escape from the conclusion that they are charges of negative electricity carried by particle of matter.” (1862)

6. Proposals for Partial Solutions

6.1 Abduction/ Inference to the best explanation

Underdetermination

A number of given hypotheses are empirically equivalent, any evidence is unable to favour one of them over the other.

Additional criteria:

Special status to explanatory considerations

Type of inference often employed both in everyday life and in scientific reasoning.

Inference from ***explanatory power*** to 'truth':

Given evidence *e* and candidate hypotheses h_1, h_2, …h_n

h_i explains *e* better than the other hypotheses

Therefore: h_i is (probably) true

e_1, e_2, …, e_n are observations

h explains e_1, e_2, …e_n better than all other alternative hypotheses .

Therefore: h is (probably) true

presupposition: a given set of hypotheses

Examples:

Winston Churchill on the beach

Orbit of Uranus

Conclusion goes beyond what is logically contained in the premises.

Widespread in everyday life and in science, but there is much discussion in philosophy of science about the justification.

Abduction versus Bayesian Conformation Theory: compatible, supplement?

6.2 Further Intuitive Rules

new predictions

confirmation effect of surprising evidence

diverse evidence

coherence

entities:

(Franklin, p. 145): if "we can reasonably infer that if the endproducts are observed, and there are no other competing processes that could produce those same products in sufficient numbers, than inverse β–decay has been observed."

„Sherlock Holmes Strategy"

holism

6.3 Again: Bayesian Confirmation Theory

Unifying conception

- Bayesian nets: account for more complex inferential structure in the theory/ experiment interface
- confirmation effect of surprising evidence, diverse evidence
- non-empirical confirmation
  - constraint: theory of rationality
  - problem of priors, metaphysical context

7. Philosophy of Science and Reflective Equilibrium

When do results of a measurement give good reasons that we have found a special physical object?

No ultimate consensus:

- Can science reveal the truth about unobservable objects?
- Can scientific reasoning be justified at all?

Statements are justified by being a part of a coherent system.

In addition: causal contact to the “external world”.

Philosophy of science: Description or normative rules?

Method: **reflective equilibrium**

introduced by Nelson Goodman (1955): justification for the principles of inductive logic

term coined by John Rawls: A Theory of Justice (1971)

endpoint of a deliberative process: reflecting and revising our beliefs

General rules are provided by what we believe to be good or by what is considered as an good example of inferential reasoning. These intuitions are systemized.

Best account for a broad range of acceptable inferences.

Working back and forth, avoiding inconsistencies

Reflective equilibrium:

State of balance arrived at by mutual adjustment among general principles and particular judgments.

Do Black Holes Exist? Yes or No?

"What does it mean, how do you know?"

What are the criteria?

Philosophy and physics (in reflective equilibrium)

How good are the reasons for accepting the existence of black holes?

The (subjective) probability/ credibility of the existence of BH is x (near to 1)

What is the evidence?

Physics

What philosophy of science is good for?

Clearing concepts and arguments

Methodology

making rules of scientific reasoning explicit, finding patterns

evaluating disputed methods

analogue gravity

no alternative arguments

Philosophy of Physics

metaphysics of spacetime

interpretations of quantum mechanics

What philosophy of science is good for?

"Philosophy of science is about as useful to scientists as ornithology is to birds"

Attributed to Richard Feynman, is he right?