computational methods for astroparticle propagation

class 6: introduction

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why do we need to consider the philosophy of our work?

- “I fully agree with you about the significance and educational value of methodology as well as history and philosophy of science. ***So many people today - and even professional scientists - seem to me like somebody who has seen thousands of trees but has never seen a forest***. A knowledge of the historic and philosophical background gives that kind of independence from prejudices of his generation from which most scientists are suffering. This independence created by philosophical insight is - in my opinion - the mark of distinction between a mere artisan or specialist and a real seeker after truth."

  [Albert Einstein in exchanges with Robert Thorton, 1944]

- "Philosophy is dead." [Stephen Hawking]
- "The philosophy of science is as useful to scientists as ornithology is to birds."

  [attributed to Richard Feynman]

ontology vs epistemology

- **ontology**
  - ✦ what exists → *Reality*, *Truth*
- **epistemology**
  - ✦ how to build knowledge → methods and validity

- what is ***Truth***?
- what is ***Reality***?
- what is the scientific method?
- what is a ***model***?
- what constitutes a *good* model?

- **realism**
  - extrapolate what scientific theories say about observables to unobservables
- **anti-realism**
  - deny the implications of a theory to unobserved entities

on physical theories

- **empiricism:** experience is the *only* source of knowledge
  - David Hume, John Locke, Francis Bacon, George Berkeley
  - different conclusions can be drawn from "same" experience
  - phenomenalism as an extreme view
- **rationalism:** knowledge *can* be obtained through reason alone
  - René Descartes, Baruch Spinoza, Gottfried Leibniz
  - things can be known *a priori*
  - mathematics as a useful tool
- **transcendental idealism:** knowledge can be acquired through a combination of our mind's innate modes and experience
  - Immanuel Kant
  - "Experience without theory is blind, but theory without experience is mere intellectual play."
  - mathematics as a powerful tool (knowledge without experience)

on physical theories

- **reductionism:** big things can be understood by looking into their individual parts.
- **physicalism:** the Universe can be fully characterised in terms of physics, even if the "right" theories haven't been found yet
- ***what about the physical laws?***


Leibniz

- Leibniz: we live in the best of all possible worlds
- **possible worlds:** everything that is physically conceivable
- possible worlds: **epistemological** resource or **ontological** entity?

the *popperisation* of science

- some say science is becoming "popperised" and it is time to revisit the scientific method
- the scientific method is essentially common sense; when it is attacked, this may lead to a crisis in trust, where expert opinion loses its value, as claims cannot be proven
- when to recognise that something is not science and stop pursuing it?
- when to stop searching for evidences to support a theory? ("stopping problem")
- are we in the era of "post-empirical science"? should we even consider it?
- how do we recognise underdetermination? when to start looking for answers elsewhere?
- to abandon our positivist approach to science is to open the door to pseudosciences

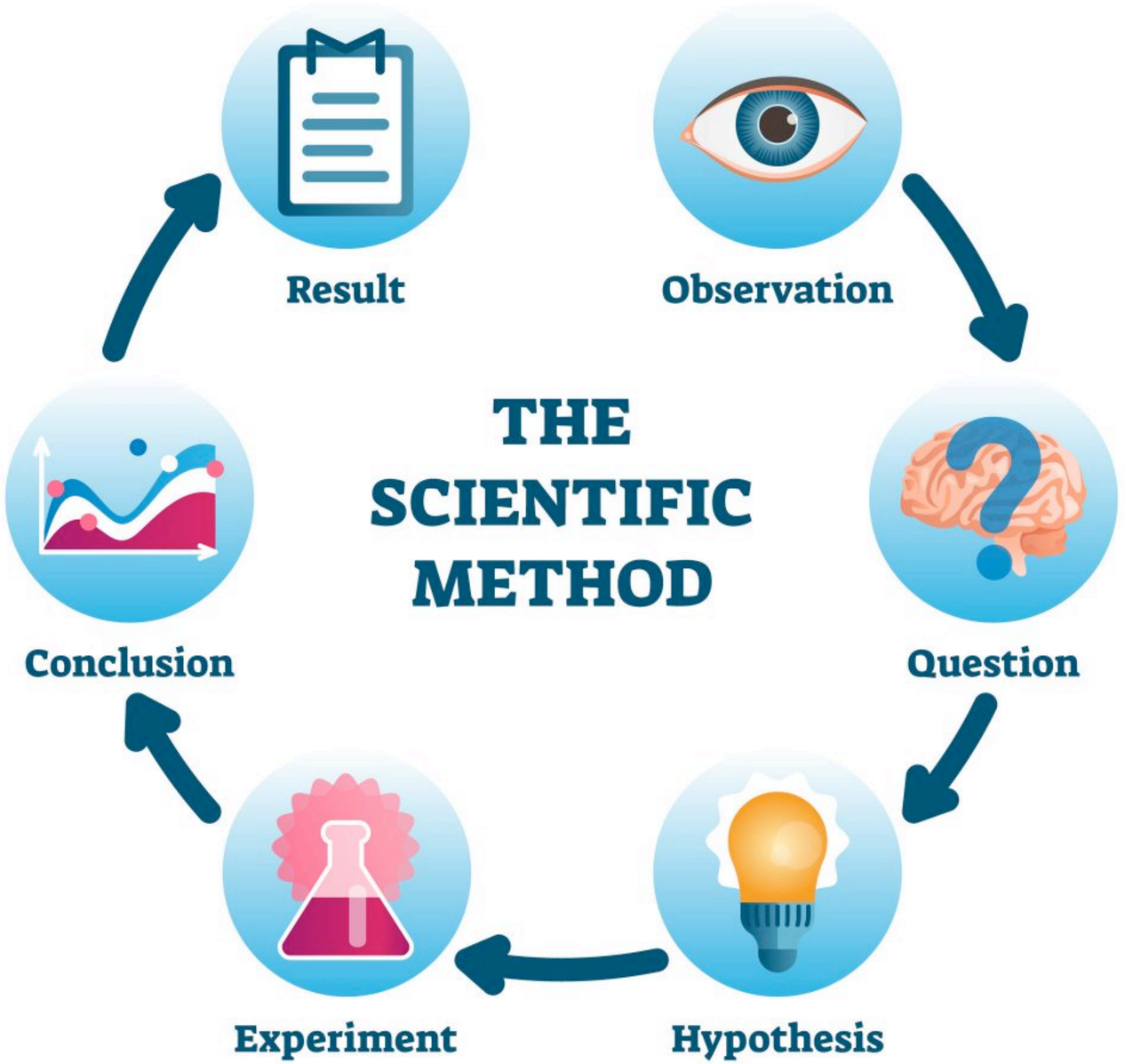
2) another case study: strings and the multiverse

Defend the integrity of physics

Attempts to exempt speculative theories of the Universe from experimental verification undermine science, argue **George Ellis** and **Joe Silk**.

Ellis & Silk; "Defend the integrity of physics"; Nature
http://www.nature.com/news/scientific-method-defend-the-integrity-of-physics-1.16535

the scientific method



models?

the problem of induction: Hume's view

Here is a billiard-ball lying on the table, and another ball moving towards it with rapidity. They strike; and the ball, which was formerly at rest, now acquires a motion. This is as perfect an instance of the relation of cause and effect as any which we know, either by sensation or reflection. Let us therefore examine it. 'Tis evident, that the two balls touched one another before the motion was communicated, and that there was no interval betwixt the shock and the motion. *Contiguity* in time and place is therefore a requisite circumstance to the operation of all causes. 'Tis evident likewise, that the motion, which was the cause, is prior to the motion, which was the effect. *Priority* in time is therefore another requisite circumstance in every cause. But this is not all. Let us try any other balls of the same kind in a like situation, and we shall always find, that the impulse of the one produces motion in the other. Here therefore is a *third* circumstance, *viz*. that of a *constant conjunction* betwixt the cause and effect. Every object like the cause, produces always some object like the effect. Beyond these three circumstances of contiguity, priority, and constant conjunction, I can discover nothing in this cause. The first ball is in motion; touches the second; immediately the second is in motion: and when I try the experiment with the same or like balls, in the same or like circumstances, I find, that upon the motion and touch of the one ball, motion always follows in the other. In whatever shape I turn this matter, and however I examine it, I can find nothing farther.

the problem of induction: Hume's view

"All inferences from experience, therefore, are effects of custom, not of reasoning. Custom, then, is the great guide of human life. It is that principle alone which renders our experience useful to us, and makes us expect, for the future, a similar train of events with those which have appeared in the past. Without the influence of custom, we should be entirely ignorant of every matter of fact beyond what is immediately present to the memory and senses." *[D. Hume, An Enquiry Concerning Human Understanding, I]*

- causality
  - contiguity
  - constant conjunction
  - possible independence

- the basis for modern philosophy of science
- knowledge necessarily comes from experience
- criterion of verifiability
- rejection of a priori statements
- towards a **unified science**

Popper's view

- the problem of induction
  - under what conditions are inductive inferences acceptable
  - must be a synthetic sentence (allows negation)
  - the principle of induction makes sense, but its proof is inductive
- Popper's view (deduction)
  - deduce the conclusions using reason
  - verify the inferred conclusions
  - corroboration vs. falsification

Lakatos's view

- from Popper we learn about the power of falsifiability
- confirming instances have no epistemic value whatsoever [Imre Lakatos]

how good is a model? a Bayesian view

Bayes's theorem

$$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)}$$

what is the probability of my theory being right?

$$P(T \mid D) = \frac{P(T)P(D \mid T)}{P(T)P(D \mid T) + P(\bar{T})P(D \mid \bar{T})}$$

- $P(T)$: prior
- $P(D \mid T)$: likelihood: how well does the theory describe the data
- $P(\bar{T})$: competing theories
- $P(D \mid \bar{T})$: how good is the competition

how good is a model? a complexity view

- **Kolmogorov complexity** is the minimum amount of information needed to perform a computation
- Occam's razor ↔ Kolmogorov complexity
- simpler models preferred → aesthetics?

"Science is built up of facts, as a house is built of stones; but an accumulation of facts is no more a science than a heap of stones is a house."

- multimessenger is ***the*** way forward
- observations of *all messengers* should be interpreted together
- *self-consistent models* are if we wish to obtain reliable conclusions

discussion: examples in astroparticle

- UHECRs
- gamma rays
- dark matter
- neutrinos
- ...?