Thinking about Natural Science

An introduction to philosophy for scientists
Lecture II

Paolo Beltrame
paolo.beltrame@liverpool.ac.uk

University of Liverpool
Department of Physics - Particle Physics Group

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Overview of the course

I) [3 Feb. 2025] Introduction and quick historical background
II) [10 Feb. 2025] Modern science and philosophical difficulties...
III) [17 Feb. 2025] (Neo)Positivism, Popper, Kuhn, Lakatos, Feyerabend
IV) [10 Mar. 2025] Case studies (I): Reality, physical world and laws of Physics
V) [24 Mar. 2025] Case studies (II): Truth, what do the theories describe?
VI) [31 Mar. 2025] Guest lecture.

Overview of today

1. Summary of Lecture I
2. Conflict(s) and new protagonists
3. Philosophical topics
4. References

Summary of Lecture I

The Historical Background

Ancient History of Philosophy of Nature

- Ancient Greek
- Medieval Philosophy

Philosophy of Physis:

Rational thought and search for the causes/explanation

Natural world

Observations

deeper, broader and more profound than modern science

no very methodologically and/or technically 'efficient'

$\Rightarrow$ Understanding the *real*, *true* nature of the world

Plato & Aristotle

Plato (c. 428–348 BCE)

- True reality: perfect and immutable *Ideas* in the metaphysical world (*hyperouranios*)

  $\rightarrow$ rational enquiry, recollection
  $\Rightarrow$ Intellect $\Rightarrow$ Rationalism

Aristotle (384–322 BCE)

- *substance* and *essence*, *actuality* ($\epsilon\nu\acute{\epsilon}\rho\gamma\epsilon\iota\alpha$) vs. *potentiality* ($\delta\acute{\upsilon}\nu\alpha\mu\iota\varsigma$)

- the causes/explanation
  $\rightarrow$ final cause, teleology

  $\rightarrow$ Induction $\Rightarrow$ Observation $\Rightarrow$ Realism
  (Forms within the material reality)

Nature of the *facts*
Nature of the *laws/theories*

The start of Modern Science

A. knowledge was based largely on authority, especially the authority of the ancient philosophers (Aristotle) and the authority of the Sacred Texts (the Bible).
B. only when this authority was challenged by an appeal to experience (facts), by pioneers of the new science (Galileo), modern science became possible.

It was not so much the observations and experiments which Galileo made that caused the break with tradition as his attitude to them. For him, the facts based on them were taken as facts, and not related to some preconceived idea...
The facts of observation might, or might not, fit into an acknowledged scheme of the universe, but the important thing, in Galileo's opinion, was to accept the facts and build the theory to fit them

Conflict(s) and new protagonists


0 100 200 300 400 500 miles
0 200 400 600 800 km
Stockholm
Derry
Glasgow
Edinburgh
Dublin
Cloyne
Chatsworth
Oxford
Cambridge
Amsterdam
London
Utrecht
Leiden
Königsberg
Wittenburg
Berlin
Halle
Leipzig
Jena
Warsaw
Paris
la Flèche
Prague
Tübingen
Augsburg
Zurich
Vienna
Geneva
Venice
Paduao
Valladolid
Pisa
Florence
Madrid
Rome
Naples
Granada

The path of philosophy

- Philosophy turned its back on Aristotle → good and evil consequences
  - *Broad sense-philosophy* (including the *natural philosophy*)
    ⇒ a great boon as Aristotle's physics was hopelessly erroneous
    The deference paid during the Middle Ages was a great brake on scientific progress
  - *Narrow sense-philosophy* (as a distinct discipline in universities)
    ⇒ losses as well as gains

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⇒ R. Descartes (1596 – 1650) (dualism between mind and matter)

⇒ British empiricism (XVII - XVIII centuries)

vs.

I. Kant (1724 – 1804) together the contributions of the *senses* and the *intellect*
(divided and distorted by both empiricists and rationalists)

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→ G.W.F. Hegel (1770 – 1831)

New Science superseded old Philosophy

1. Heliocentrism supplanted geocentrism

   Ptolemy (c. 100–178):
   Earth is a sphere and does not move, at the center of the cosmos

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   the Sun, Moon, planets and stars – are embedded in perfectly concentric ethereal spheres that rotate eternally at fixed rates

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3. New physics: quantitative methodology

   Aristotle (384–322 BCE):
   Terrestrial objects rise or fall according to the ratio of the four elements of which they are composed
   'Everything that moves is moved by something else (*Omne quod moventur ab alio movetur*)' *Physics, 8, Ch. 10, 267*^{a}

Nicolaus Copernicus (1473–1543)

Aristarchus of Samos (c. 310–230 BCE) $\Rightarrow$ the Sun is at the centre of the universe, but rejected by others for common-sense reasons

- born in Poland, attended the University of Krakow
- to Renaissance Italy (law, medicine and classics, in Bologna, Padua and Ferrara)
- in 1506 back to Poland, a canon at Frombork Cathedral and practiced medicine

Not a revolutionary $\Rightarrow$ improving, not replacing, the Ptolemaic system
$\Rightarrow$ retrograde motions of some of the planets
Simpler and more elegant *description* $\rightarrow$ the Sun at the centre of the universe

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$\Rightarrow$ retrograde motions of some of the planets
Simpler and more elegant *description* $\rightarrow$ the Sun at the centre of the universe

Still required epicycles and not much simpler (or more accurate)
However it solved some of the problems and was certainly more elegant

The ‘common-sense’ issues

Conflict between common sense and a new method

$\Rightarrow$ Objects on the Earth share in its motion around the Sun

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De revolutionibus orbium coelestium (On the Revolution of the Heavenly Spheres)

- Dedicated to the Pope
- Published in 1543, the year he died
- Little attention, until the XVII century → banned by the Roman Catholic Church

- Tycho Brahe (1546–1601)
  ⇒ Johannes Kepler (1571–1630):
Three laws of planetary motion → *Rudolphine Tables* (1627)

Galileo Galilei (1564–1642)

- Mathematics to describe the motions of objects
- Experiments to test hypotheses
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Inquisitive mind, he loved to argue, questioned the Aristotelian wisdom of the time
$\Rightarrow$ Unlike Aristotle he thought that all objects fall at the same speed

Experiments with balls rolling down inclined planes $\rightarrow$ balls accelerate at the same rate due to gravity
$\Rightarrow$ The same in free-fall, just an *extreme case* with the inclined plane vertical

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Inertia $\rightarrow$ imagined a ship at constant speed: everything on the ship behaves as the ship at rest. All bodies in motion tend to maintain that motion


TVBVM OPTICVM VIDES GALILAEI INVENTVM, ET OPVS, QVO SOLIS MACVLAS,
ET EXTIMOS LVNAE MONTES, ET IOVIS SATELLITES, ET NOVAM QVASI
RERVM VNIVERSITATE PRIMVS DISPEXIT A. MDCIX.

New instrument: the telescope

- In 1609 Galileo in contact with the invention of the telescope (Dutch Hans Lippershey)
→ magnifying power of 20–30 times

→ Pointing the telescope to the skies
  - Four moons of Jupiter orbiting around Jupiter itself
    (*proving* that not everything just moves around the Earth)
  - Mountains and craters on the Moon
    (not anymore the perfect sphere as the ancients had imagined)
  - Countless stars comprising the Milky Way
  - Phases of Venus
    (could only be explained if Venus orbits the Sun)
  - Spots on the Sun
    (the Sun is also not the perfect heavenly body)

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→ *Siderius Nuncius (The Starry Messenger)* in 1610
Lifetime post as *Philosopher and Mathematician* to the Grand Duke of Tuscany

... Conflicts

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- Galileo careful not to promote the Copernican model itself

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- Galileo careful not to promote the Copernican model itself

  - Good relations with members of the Church hierarchy, including the Pope himself
  - Aristotelian sceptics of Galileo's observations $\rightarrow$ may be due to artefacts of his telescope
  - In 1616, the idea of the Sun at the centre of the universe declared heretical
  - *De Revolutionibus* was banned by the Church
    $\Rightarrow$ Galileo must not support or teach the Copernican worldview
  - In 1623 Urban VIII, new Pope $\rightarrow$ permission to Galileo for a book about the two systems of the world

Dialogo sopra i due massimi sistemi del mondo (Dialogue on the Two Chief World Systems), 1632

DIALOGO
DI
GALILEO GALILEI LINCEO
MATEMATICO SOPRAORDINARIO
DELLO STVDIO DI PISA.
E Filosofo, e Matematico primario del
SERENISSIMO
GR. DVCA DI TOSCANA.

Doue ne i congressi di quattro giornate si discorre sopra i due
MASSIMI SISTEMI DEL MONDO
TOLEMAICO, E COPERNICANO;

Proponendo indeterminatamente le ragioni Filosofiche, e Naturali tanto per l'vna, quanto per l'altra parte.

CON PRI VILEGI.

IN FIORENZA, Per Gio: Batista Landini MDCXXXII.

CON LICENZA DE' SVPERIORI.

Dialogue on the Two Chief World Systems

- Salviati (for the Copernican case) and *Simplicio* (for the Ptolemaic case)
- The Pope and the Church felt 'insulted'
$\rightarrow$ investigate, Galileo was ordered to stand trial before the Inquisition for heresy
- *'I abjure, curse and detest my errors'*

- Lifetime house arrest $\Rightarrow$ villa in Arcetri (Tuscany, Italy)
$\rightarrow$ *Discourses and Mathematical Demonstrations Concerning Two New Sciences*, 1638 in Leiden (Netherlands)

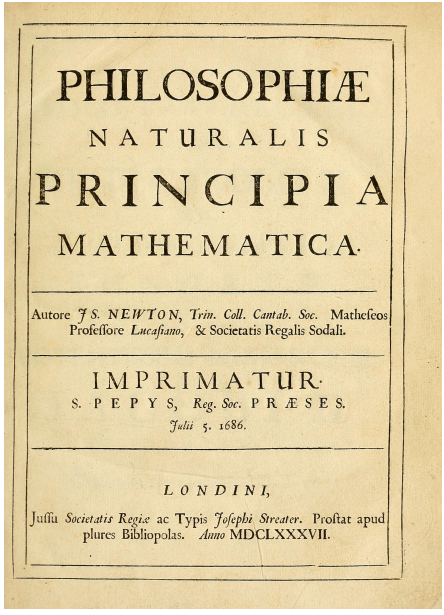
Scientific method
the importance of observations and repeated experiments to test hypotheses

Isaac Newton (1642–1726)

- Into Trinity College, Cambridge at the age of 18
- Ignore much of the formal curriculum $\rightarrow$ studying whatever he wanted: great works of science and mathematics
- Plague, 1665 and 1666 his *annus mirabilis*

- Light as a stream of particles (which he called *corpuscles*), in contrast to the views of others according to whom light is a wave phenomenon
- *De motu corporum in gyrum* (On the Motion of Bodies in Orbit), during 1684 in dialogue with Edmund Halley (1656–1742), proving the Kepler's three laws

- *Philosophiae Naturalis Principia Mathematica (Mathematical Principles of Natural Philosophy)*, published in 1687



PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.

Autore *J. S. NEWTON, Trin. Coll. Cantab. Soc.* Matheſeos Profeſſore *Lucaſiano,* & Societatis Regalis Sodali.

IMPRIMATUR.
S. PEPYS, *Reg. Soc.* PRÆSES.
Julii 5. 1686.

LONDINI,

Juſſu *Societatis Regiæ* ac Typis *Joſephi Streater.* Proſtat apud plures Bibliopolas. *Anno* MDCLXXXVII.

Few more words on Newton

$\rightarrow$ The shackles of the ancient Aristotelian qualitative worldview were broken

- Precise, quantitative and workable worldview
- The universe and all its contents work according to *fixed laws*
  $\rightarrow$ accurate predictions possible

$\Rightarrow$ *'clockwork'* universe

monumental synthesis of

- heliocentric theory of Copernicus
- Kepler's laws of planetary motion
- Galileo's physical ideas

Laws of Physics are fixed, well determined and universal
A wide variety of phenomena could be mathematically explained and predicted

Modern science was born

Philosophical topics

Philosophy and embryonic Modern Science

F. Bacon (1561 – 1626)

- guiding spirit of the Royal Society
- *Novum Organum*

Significant detachment from Aristotle's $\Rightarrow$ metaphysics in a novel way

Natural philosophy speculative or operative:

$\rightarrow$ speculative: both physics and metaphysics

$\rightarrow$ operative: both mechanics and magic

Tree: Physics $\Rightarrow$ efficient and material causes

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Tree: Physics $\Rightarrow$ efficient and material causes
Root: Metaphysics $\Rightarrow$ final and formal causes

Natural Philosophy

Single discipline of *natural philosophy*

1. Philosophy of natural science $\rightarrow$ understanding of the concepts in describing natural phenomena: *space*, *time*, *motion*, and *change*
2. Science of physics $\rightarrow$ establish and explain the phenomena themselves, by o*observation*, *experiment*, and *hypothesis*

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Aristotle's natural philosophy (elements of both disciplines indiscriminately entwined)
$\Rightarrow$ battle on the authority
The Aristotelian yoke was thrown off $\rightarrow$ sciences gathered impetus

$\rightarrow$ Against the system, coming from outside the academic main-stream:
Galileo, Bacon, and Descartes

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Sadly, the liberation of physics was accompanied by an impoverishment of philosophy
⇒ Aristotle's scheme retained much of its value

Galileo

The scholastic professors (teacher of Aristotle's philosophy)
$\rightarrow$ blamed for preferring *a priori speculation* to observation and experiment

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→ blamed for preferring *a priori speculation* to observation and experiment

→ Not totally correct

A. Kenny, *A New History of Western Philosophy - Volume 2*, p.166-167

Aristotle affirmed the primacy of fact over speculation:
'We must trust observation rather than theory,
and trust theories only if their results conform with the observed phenomena'

Aristotle, *On the Generation of Animals* 3. 10. 760^b28–31

The dilemma of Authority

Ipse dixit $\rightarrow$ he said it himself
An assertion without proof, or a dogmatic expression of opinion

- Aristotle's works rediscovered in the Latin West (predominantly text-based)

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Supreme authority rested with the Bible:
Church $\rightarrow$ preserve, proclaim, and interpret the messages contained in that book

- Aristotle treated with the reverence appropriate to a sacred book

Galileo's contradictions of Aristotle $\rightarrow$ scandal as if they contradict the Bible

Scientific method

The elementary understanding:

1. Systematic observation is undertaken of the phenomena to be explained
2. Theory is proposed which would provide an explanation of these phenomena
3. From this theory is derived a prediction of some phenomenon other than those already included in the survey
4. The prediction is tested empirically
   - if the prediction turns out false, than the theory is to be rejected
   - if it comes true, then the theory is so far confirmed

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Mathematics plays a crucial role

Difficulties

Aristotle, Descartes, Bacon, Galileo
- Fail in appreciating one or other element needed for the synthesis
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Bacon: *Novum Organum* methodology for systematic 'data taking' to formulate hypotheses
$\Rightarrow$ Little appreciation of mathematics (a mere appendix to science)

Difficulties: Galileo

The book of the universe *is written in the language of mathematics, and its characters are triangles, circles and other geometric figures, without which it is humanly impossible to understand a single word of it*

G. Galilei, *Il Saggiatore*, 6

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Weakest point (insisted on by his Aristotelian opponents)
$\Rightarrow$ Hypothesis is only confirmed by the success of a prediction, not proved with certainty

Pierre Duhem (1861 – 1916), Karl Popper (1902 – 1994), Paul Feyerabend (1924 – 1994):
Bellarmine victorious in the debate on heliocentrism

René Descartes (1596 – 1650)

The essence of matter is *extension*

- Mathematics the key to physics, not Galileo's grasp on mathematics for the experiments
- Physical system is mechanistic $\rightarrow$ natural phenomena motion of matter (*materialism*)

  - No need for models from the scholastic theory
    $\rightarrow$ whole nature in terms of *motion* and *extension*
  - No empty space/vacuum $\rightarrow$ matter $\equiv$ extension

God created matter along with *motion* and *rest*
Total quantity of motion in the universe is constant
variations in accordance with the *laws of nature*

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$\Downarrow$

Laws of nature deduced *a priori* from the immutability of God

Philosophical recap (I)

Deductive vs. inductive and method

- A priori reasoning; *Rationalism* → problem of external/physical world → *Idealism*
  If the premises are true then the conclusion must be true. Logic is truth preserving
  A. Chalmers, *What is this thing called Science?*, p.39
- Experiments and Observations; *Empiricism* → problem of inductive method
  Example of the *turkey*, attributed to B. Russell (1872 – 1970)

→ Tentative solution Immanuel Kant (1724 – 1804)

Realism

Veritas est adaequatio intellectus ad rem (truth is the adequation of intellect to thing)

Thomas Aquinas, *De veritate* (On truth) q.1 a.1

Mechanicism and Determinism

- Dualism: Descartes → *res cogitans* and *res extensa*

R. Descartes, *Principia Philosophiae* (Principles of Philosophy)

Philosophical recap (II)

Uniformity of the laws of physics

- What is relevant?
- No more distinction between the sublunar and superlunar/celestyal world
  - Aristotelian approach in contrast to Platonic approach (III century BCE)
  - Galileo's works (XVII century)
    In attempting to find the essence, I find it no less impossible and no less vain an endeavour in the next elementary substances than in the remotest and most remote celestial ones...

    G. Galilei, *Lettera a Cristina di Lorena* (Letter to Christina of Lorraine), March 1615
  - Descartes $\rightarrow$ no need for accidents and forms (scholastic theory)

Metaphysical horizons fade away

A troubled and exciting time

A troubled and exciting time
More questions to come...

A troubled and exciting time
More questions to come...
perhaps some explanations

References

- A. Kenny, *Modern Philosophy (A New History of Western Philosophy - Volume 2)*, Oxford Univ. Press, 2004.
- P. Shaver, *The Rise of Science*, Springer, 2018.
- A. Chalmers, *What is this thing called science?*, Univ. of Queensland Press, 1976.

Backup Slides

Europe (like Greece) $\rightarrow$ variety of different regions and states
$\Rightarrow$ Galileo's findings and ideas were free to flourish in the rest of Europe

The ‘common-sense’ issues

Why do things not fly off the spinning Earth?
Why do we feel no great constant wind from the east?
Why do objects fall straight down onto the Earth rather than towards the west?
Why do birds have no more difficulty flying east than west?
Why does a cannonball go the same distance east or west?

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Three laws of planetary motion

1. Planets move in elliptical orbits around the Sun (not circles)
2. The line from the Sun to a planet sweeps out equal areas in equal times
3. The square of the period of a planet's orbital motion is proportional to the cube of its average distance from the Sun

$\rightarrow$ In 1627 a new set of tables, the *Rudolphine Tables*