Freiburg Institute for Advanced Studies

FRIAS Lunch Lecture Series: Paradigm Shifts in Science

Paradigm Shifts in Physics

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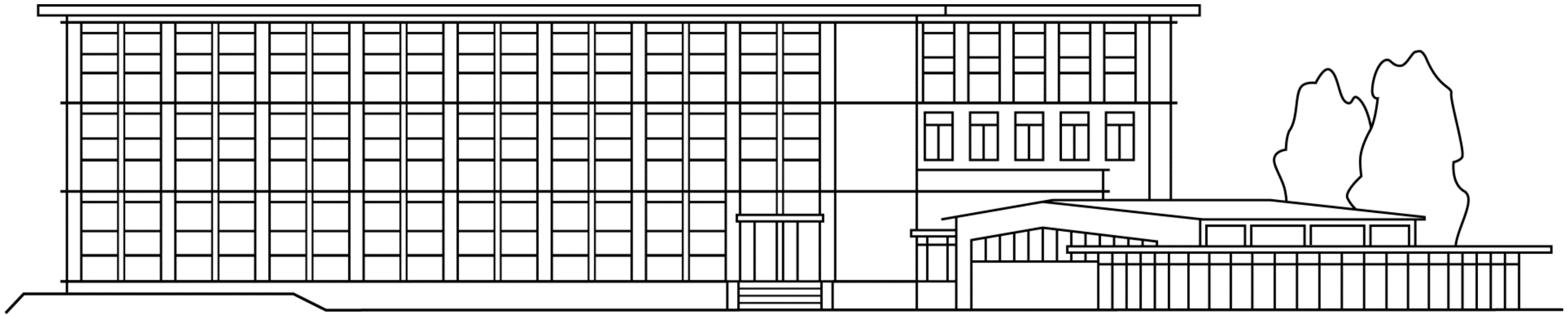

Previous lecture: Paradigm Shifts in Linguistics

- *Paradigm:* the way the majority does science
- *Progress:* cycle of paradigms,
  paradigm shift unrelated to progress

Last week:
Paradigm Shifts in Linguistics

- *Paradigm:* the way the majority does science
- *Progress:* cycle of paradigms,
  paradigm shift unrelated to progress

This week: Paradigm Shifts in Physics

“Kuhn [is] the most influential philosopher of science—I mean the most widely read, and to some extent believed, by practicing scientists.”

Ian Hacking, 2012

Outline

- Introduction: progress in science?
- Kuhn's paradigms and scientific revolutions
- Physics example I:
  from Newtonian mechanics to special relativity
- Physics example II:
  from classical to quantum mechanics
- Kuhn revisited
- Discussion

Introduction: progress in science?

“If I have seen further, it is by standing on the shoulders of giants.”

Isaac Newton, 1676

Introduction: progress in science?

"If I have seen further, it is by standing on the shoulders of giants."

Isaac Newton, 1676

- *"I have seen":* There is some truth that science is trying to discover.
- *"Further":* Science can make progress towards discovering this truth.
- *"Standing on the shoulders of giants":*
  This progress happens by adding new knowledge to existing knowledge.

Kuhn's paradigms and revolutions

Thomas Kuhn: Historian/philosopher of science
The Structure of Scientific Revolutions (1962)

Central thesis: Scientific progress “jumps”

Provocative statement:
“The scientific enterprise as a whole does from time to time prove useful, open up new territory, display order, and test long-accepted belief. Nevertheless, the individual engaged on a normal research problem is almost never doing any one of these things.”

Thomas S. Kuhn, 1962

What “jumps”? Paradigms

Normal science: work within paradigm

Paradigm = disciplinary matrix

- *Symbolic generalizations:*
  laws of nature + interpretation
- *Metaphysical beliefs:* philosophical assumptions
- *Values:* judging predictions + theories
- *Exemplars:* model problems + solutions

How does it “jump”? Revolution

Extraordinary science: scientific revolution

- *Normal science:* steady extension of knowledge, adding of detail to paradigm
- *Anomalies:* new facts that do not fit within paradigm
- *Crisis:* questioning of paradigm, proliferation of competing ideas
- *Scientific revolution:* establishment of new paradigm

New paradigm: incompatible with old paradigm

Example I: Newtonian mechanics

- *Primary quantities:* space and time (independent of each other)
- *Length* and *duration* independent of state of observer
- *Secondary quantity:* velocity=length/duration; variable property of an object.
- Velocities can be *added* like numbers

Typical problem:
Determine trajectory of objects under influence of forces (e.g., planets, pendulum, ...)

Example I: Special Relativity

Crisis:
Experiment: speed of light c seems to be universal
Contradiction: Mechanics vs. Electromagnetism

- *Primary quantity:* constant speed of light c
- Length and duration depend on state of observer (*reference frame*)
- Space and time are *interdependent*
- Non-trivial *velocity addition*: v+c=c, c+c=c

Example I: Special Relativity

Typical problem:
Determine the **properties** and behaviour of objects under the influence of forces given a **specified frame of the observer**

Incompatibility:
Length contraction: length of an object?
Time dilation: Duration of an event?
Rigid body: there is no such thing

Example II: Classical mechanics

- *Primary quantities:* position and velocity (independent of each other and of observer)
- *Determinism:* motion of object can be completely and accurately predicted
- *Chance:* only due to inaccurate knowledge/measurements

Typical problem:
Determine complete trajectory of objects given their initial positions and velocities (e.g., planets, pendulum, ...)

Example II: Quantum mechanics

Crisis:
Puzzle: Unexplained stability of the atom
Experiment: Poorly understood black-body radiation

- *Primary quantities:* energy, wave function
- *Chance:* only probabilities for measurement outcomes can be predicted
- *Uncertainty:* position and momentum cannot be accurately measured simultaneously

Example II: Quantum mechanics

Typical problem:
Determine the **energies** and **wave functions** of a system which can be used to **predict measurement outcomes**.

Incompatibility:
No trajectory: position and velocity not known
Complementarity: results depend on what type of measurement the observer performs
Entanglement: disagreement with classical probability theory

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Kuhn revisited

	Relativity	*Quantum mechanics*
Crisis	Yes	Yes
Change of paradigm		
Laws of nature	Yes	Yes
Philosophy	Yes	Yes
Values	Yes	Yes
Exemplars	Yes	Yes
Incompatibility	Maybe	Yes

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Discussion

- Is Kuhn's description correct for physics?
- Scientific revolution = progress?
- Progress without scientific revolutions?
- Negative view of everyday scientist: accurate? desirable?

Further reading

T. S. Kuhn: *The Structure of Scientific Revolutions*
(Chicago Press, Chicago, 2012)

S. Y. Buhmann: *Philosophy + Physics Teaching*
(Assignment, Imperial College London, 2013)

Next FRIAS Lunch Lecture on Paradigm Shifts in Science

Thursday, November 19th, 12.15 p.m. – 1.00 p.m.

Dr. Benoît Dillet
FRIAS Junior Fellow, Political Theory, Loughborough University

The Ontological Turn in Contemporary Political Theory (1990-2015)

The post-2008 global financial crisis, the 2011 Arab Spring, the Occupy movement and the 2013 Edward Snowden controversy have challenged traditional political theories and categories. Concepts such as the state, power and identity have become inadequate to think our present. We seem to lack new tools to account for these changes and to invent the future, especially in the age of the Anthropocene and the digital revolution. In this FRIAS lunch lecture, I want to briefly map out some of the main changes that have taken place in normative political theory and contemporary political theory in the last 25 years to situate the 'ontological turn' in the field. This ontological turn has allowed us to think, for instance, non-human agency beyond the nature/culture opposition, the artificial and human nexus, as well as the new regimes of truth found in re-organised neoliberal societies.