Vienna Indeterminism and the Problems of Quantum Mechanical Causality

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0. The Significance of the Causality Debate for the History of QM

Forman and beyond

The Forman Thesis

- ‘Weimar Culture, Causality, and Quantum Theory, 1918-1927: Adaptation by German Physicists and Mathematicians to a Hostile Intellectual Environment’ (1971).

1. Weimar Culture as an Intellectual Environment that was hostile to science, in particular if compared to the WilheIminian Empire.
2. Adaptation of scientists to the demands of the milieu (Spengler and the sentiment of crisis).
3. Conversions to acausality before this was required on purely scientific grounds.

The Forman Debate

- A large number of emblematic citations took Forman as precursor of SSK.
- But he rejected these developments as postmodernist and holds that, in 1927, it was simply rational to accept acausality.
- Served as a kind of shibboleth for historians of QM – even though hardly anyone accepted the thesis in its entirety.

A Causal Influence?

- Was Forman' claim of causal adaptive influence a Pavlovian scheme or only irony?
- Rejected by virtually all investigators.
- Various attenuations: strong influence.
- Forman considers them just as confirmations of the authors' bias that there exists an independent intellectual life.
- A few studies applied the model to other contexts, e.g. Kramers.

Lessons from the debate

- We cannot come up with a merely internalist narrative of the causality debate. We need:

1. a *historical* characterization of the style of philosophizing among German physicists.
2. a *sociology* of how and in which media this debate was conducted.
3. a detailled *philosophical* reconstruction.

Lessons 2

- Forman, Beller, Cushing etc. fell short of such a broader approach because they strictly separated science and (academic) philosophy.
  - ¬ no genuine philosophical convictions, but only rhetoric and ideological justification.

Main Theses

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Main Theses

1. The causality debates in Weimar Germany and interwar Austria were an integral part of a much longer causality debate that emerged from two different readings of Boltzmann's legacy, statistical mechanics, at the end of the 19th century and ended only in the late 1930s, when the philosophical debates surrounding quantum mechanical indeterminism abated and the focus was shifted to locality and realism.

Main thesis 2

2. Most physicists seriously pondering about causality had taken their general philo-sophical stand already long before 1918.
3. The complex but continuous debate, after 1913, mainly appeared on the pages of the leading scientific journal of the German-speaking world, *Die Naturwissenschaften.*
4. Thematically, the relationship between causality and probability was pivotal.

Main thesis 3

5. The role model of physicist-philosopher and its pervasiveness is crucial for the social impact of this debate.
6. Other than guilded philosophers, physicist-philosophers were part of more than one thought collective.
7. To appraise the historical dynamics of a philosophical concept, the historical approach must be accorded with methods of the history of philosophy (of science).

Overview

1. The physicist-philosophers and their main forum.
2. Vienna Indeterminism and the causality debate.
3. A snapshot of Logical Empiricism

1. The physicist-philosophers and their main forum

1. Typical Scheme
2. Die Naturwissenschaften
3. Strategic Alliances

The role model

- physicist-philosopher as a specific trait of the German-speaking scientific cosmos from the 1860s until the end of the Weimar republic.
  - **ubiquity** and pervasiveness of the philosophical ambitions.
  - strength of these ambitions could vary.
- manifold opportunities to lecture and publish on philosophical issues
- two influential founding fathers, Helmholtz and Mach, who had overcome the older *Naturphilosophie*.

Typical scheme

1. Addresses delivered to the whole university or an academy went through various journals and were later assembled into separate books.
2. The appearance of such a book typically testified the author's becoming a physicist-philosopher.
3. Specific journals, among them *Vierteljahrsschrift für wissenschaftliche Philosophie* (until 1916) and Ostwald's *Annalen der Naturphilosophie* (until 1921)
4. After 1913, the debate would mainly take place in *Die Naturwissenschaften.*

Die Naturwissenschaften

- Aimed to “follow the major developments within the whole of natural science and present them in a generally comprehensible and captivating form”.
- Philosophical papers carefully planned by Berliner.
  - Education program including Kant, Goethe, Schopenhauer.
  - Authors from the emerging tradition of Logical Empiricism.
  - Philosophical papers penned by physicists.
- an important stronghold in the ‘defense belt’ around Einstein and relativity theory.
- Broad coverage of atomic physics.
- took a firm stand against the Spenglerian challenge.
- talk about “crisis” was accompanied with strategies to overcome it rather than rhetorics of surrender.

Paul Riebesell (1920)

- “Science – not the philosophy of nature – will now as before stick to the principle of causality and will approach precisely Spengler’s problem of the predetermination of history with its new methods. For, by means of statistical laws – which Spengler incidentally does not recognize as mathematical laws – one has already successfully analyzed those mass phenomena, which historical questions are all about.”
- ¬ Talk about statistical causality (also motivated by population statistics).

What is this embedding like?

- Do the *Naturwissenschaften* represent a progressive, science-friendly submilieu?
  - Emphasizes cultural role and unity of science.
  - More specific identity than just “Bildungsbürger.”
  - Took sides in key debates (relativity, Spengler).
- But did *NW* really overcome the intellectual fragmentation of the Weimar society?
- The submilieu thesis forces us to accept Forman’s alternative retrenchment vs. adaptation.

What then?

- So at best an operationalist usage of milieu denoting that by taking sides in the struggles about relativity theory, NW had opted for the “modernists” among physicists.
- Part of an Fleckian, onion-like structure of science popularization. (Schirrmacher)
  - λ True, but the philosophical discourse occurred mainly in *Die Naturwissenschaften*.

What then? - 2

- Fleckian thought collective? (Sigurdson)
  - Rather did NW harbor many Fleckian thought collectives from different disciplines.
  - Among them LE and Göttingen-Copenhagen.
  - After all, scientific modernism could mean different things in different disciplines.
- Singular nature of Arnold Berliner, who cherished the Helmholtzian intuition that the basic problems of science are of a philosophical nature and developed it in the new context of Weimar republic.
  - In this perspective it is natural that papers of Bohr, Heisenberg, Born, Planck appeared side by side with LE.
  - Cf. also correspondence after Schlick's paper.

Strategic alliances among physicist-philosophers

1. There is a set of basic philosophical convictions that a group of scientists considers as central in order to further their philosophical agenda within a particular intellectual, social or disciplinary context.
2. Confine their disagreements to internal discussions.
3. In retrospect, disagreements may appear substantial.
4. As the convictions which are considered pivotal within the respective context undergo changes, the members of a strategic alliance regroup.
5. The philosophical ambitions expressed in their agendas are not exhausted by the intersection constituting this strategic alliance.

Are the physicist-philosophers simply opportunists?

- Little, if any, school allegiance.
  - λ But the free usage of philosophical concepts is counterbalanced by the problem-specific character of the philosophical considerations.
  - λ Important role of local traditions (Mach, the Boltzmann school, Planck)
- Rather than change on an ad hoc basis, the philosophical convictions remain constant on a time scale larger than any specific inner-scientific development.

Stratification

- Revision of philosophical orientation prompted by a change in the conceptual structure of science.
  - λ Do we need a modified notion of causality?
- Philosophical discussions typically occur around 'scientific revolutions'.
- Scientists often search for an epistemological underpinning of their basic concepts, however classified in disciplinary terms.
- ¬ Stratification of knowledge rather than disciplinary conflict or different subject matters.
- ¬ Different levels on different time-scales.

Some time-scales of the causality debate

- 1870-1945: descriptivist causality versus causal explanation.
- 1908-1936: Vienna Indeterminism versus Planck-Schlick.
- 1918-1926: The crisis in atomic physics coincides with the years of political turmoil.
- 1918-1922: Spengler debate coincides with the struggles about relativity theory.

2. Vienna Indeterminism

Franz Serafin Exner‘s synthesis of Mach and Boltzmann

The context of Exner‘s inaugural address (1908)

- Boltzmann employed Mach‘s radical empiricism against his primary opponent energeticism.
- The late Boltzmann (1895-1906) contemplated that basic concepts, e.g. time, were atomistic and that even the law of energy conservation was only valid statistically.
- Exner depicted an empiricist Boltzmann and introduced the relative frequency interpretation of probability into the debate about causality.
- 2nd law as the “supreme law of nature”.

„Über Gesetze in Naturwissenschaft und Humanistik“ (1908)

- (i) in physics “we observe regularities which are brought out exclusively by chance” but whose probability is so high “that it equals certainty for human conceptions”
- (ii) in the domain of the humanities and the descriptive sciences “the random single events succeed one another too slowly [such that] there can be no talk about a law.”

Two concepts of causality

- **Kantian**: to stand in a causal relationship is a condition of the possibility for the reality of a physical object (empirical realism),
- **Machian**: causality consists in functional dependencies between the determining elements, and ‘facts’ consist in stable complexes of such dependencies.
  - “Prinzip der schlampigen Naturgesetze” (Sommerfeld)
  - More flexible in choosing an ontology (basic facts).

Two concepts of probability:

Von Kries' *Spielraumtheorie*

- Nomological and ontological regularities ("Gesetzmäßigkeiten")
- Natural laws define the range that is filled by probabilistic regularities.
- ¬ Separation between deterministic laws and probabilistic regularities.
- ¬ Endorsed by Boltzmann (1886), but only once.

Two concepts of probability:

Fechner's *Kollektivmaßlehre*

- Probability is the limit of relative frequencies:
  1. This limit exists.
  2. Irregularity of coordination.
- Collective a possible object of scientific theory (Richard von Mises).
- But it exists only for infinitely many trials.
  - λ Only reconcilable with Machian causality.
  - λ And a conventionalist treatment of theory.
- There exists a region of transition between the macroscopic and the microscopic domain.

Three core tenets of VI

(1) The highly *improbable events* admitted by Boltzmann's statistical derivation of the second law of thermodynamics exist.

(2) To the empiricist, the *burden of proof* rests with the determinist who has to provide a sufficiently specific theory of microphenomena because he introduces a dualist account.

(3) Fechner's relative frequency interpretation of probability (as a basis for macroscopic entities).

Planck‘s obections (1914)

(1) Molecular disorder is a supplementary condition that rules out these highly improbable events.

(2) Causal laws are a precondition of scientific explanation (and of the entities accepted).

(3) Probability theory requires a deterministic foundation that specifies what is nomologically possible (the Kriesian *Spielraum*).

λ Notice that Planck’s polemics against Mach was grounded in a defense of Boltzmann.

Dramatis personae

1. Vienna Indeterminism:
    1. Franz Serafin Exner,
    2. Erwin Schrödinger
    3. Philipp Frank, Richard von Mises,
2. Max Planck and (the early) Moritz Schlick as the opponents of VI.
3. Hans Reichenbach advocated a position that (initially) combined elements of 1. & 2.
4. Also others were influenced by the different readings of Boltzmann's statistical mechanics. (cf. Nernst, Riebesell, Sommerfeld).

Historical Dynamics

- While Schlick had to revoke his first theory of causality after 1926, VI and Reichenbach could feel themselves confirmed.
- All stressed Exner‘s priority for indeterminism while Schlick repeatedly denied it.
- Schrödinger never changed his mind about the merits of indeterminism, but he temporarily considered the issue a matter of convention rather than empirical fact.

Divergences within VI

- Over the 1920s, differences in physical ontology emerged between Schrödinger and the VC.
- While VC took a linguistic (and axiomatic) turn, Schrödinger remained committed to Boltzmann's Bild-realism, within which "limits of language" were problematic.
- He rejected Schlick's verificationism.
- Not least a consequence of the formation of a new discipline "scientific philosophy" from within the debate among physicist-philosophers.
- ¬ VC developed methodological strictures.

A Berlin resonance of VI: Walther Nernst (1922)

- “Among all laws [of physics] the thermodynamical ones occupy a distinctive position because unlike all others they are not just of a special kind, but applicable to any process one can imagine.”
- If one related all physical laws to the second law of thermodynamics, this would not reduce their rank; “it would however put an end to the logical overuse of the laws of nature.”

- Nernst rehearses the empiricism of the late Boltzmann, while in the perspective of Planck's reading of Boltzmann, Nernst was tampering with scientific methodology.

Boltzmann's colleagues in Graz 1887

3. A snapshot of Logical Empiricism (1929/30)

Frank, Schlick, Reichenbach at the eve of a new scientific discipline

Common elements

- The law of causality is changeable and adapts itself to the progress of science.
- Physics requires an objective notion of probability.
- Against the “metaphysical misinterpretations of quantum mechanics”, especially the return of teleological elements and the freedom of the will. Primary targets were Jordan and Sommerfeld.
- Nothing was in principle unknowable by means of scientific inquiry.

A triangle of disagreements

1. Frank and Reichenbach permitted that the basic laws of nature were statistical, while Schlick rejected talk about statistical laws (rather than “Gesetzmäßigkeiten”) and demanded the separation into law and randomness.
2. Frank sought for an empirical meaning of the general law of causality, while Schlick and Reichenbach held that it contained presuppositions of a non-empirical nature.

A triangle of disagreements 2

3. To Frank and Schlick, Newtonian mechanics, geometry, and any statistical theory represented a set of symbols and relations that were coordinated to experience.
   For Reichenbach, statistical theories were of a special kind, since the coordination itself necessarily contained statistical elements.

New strategic alliances: Copenhagen 1936

- In the mid-1930s, the main agenda of LE was to combat metaphysical misinterpretations of QM.
  - Pascual Jordan's claims about a return of vitalism.
  - Slogan that "the new physics is not mechanical but mathematical".
- On the 1936 Congress for the Unity of Science, Frank and Schlick advocated an empiricist reading of Bohr's complementarity.
- Alienation from Schrödinger, who remained an indeterminist but disliked an ontology that had limits of meaning.

New strategic alliances and the end of the causality debate

- With EPR the philosophical focus among physicist-philosophers in understanding qm indeterminacy shifted from causality to realism and locality.
- This new pivotal issue was of less concern to Logical Empiricists, even a bit suspicious.
- After Berliner's dismissal in 1935, the forum for the debate with physicists had disappeared.
  - Schrödinger's cat paper was among the last.
  - Born criticized him for this choice of journal.

Conclusion

- A very specific kind of philosophical discourse accompanied the emergence of quantum theory in the German-speaking world.
- Physicist-philosophers had genuine philosophical ambitions and were thus receptive to philosophical arguments.
- These ambitions was well-embedded sociologically and there were identifiable thought-collectives.
- This specific interaction ended in the 1930s because of the rise of Nazism and the formation of a new discipline of philosophy of science.

The End