Cassirer and Vienna Indeterminism

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Introduction

(Stöltzner 1999, 2002, 2003)

Vienna indeterminism: tradition centered on Exner, the '**historical link**' between Mach and Boltzmann, and von Mises and Frank

- Schlick (1931) showed a **rapprochement** with Vienna indeterminism;
- Cassirer (1936) showed a stronger **convergence** with Vienna indeterminism.

Cassirer appears to embrace all key tenets of Vienna indeterminism that Schlick rejected

- Exner's (1919) thesis of the **fundamentality** of statistical law,
- von Mises's (1928) **frequentist** interpretation of probability,
- Frank's (1932) and von Mises's (1930, 1934) **statistical** interpretation of the uncertainty relations

- Literature on Cassirer and the Vienna Circle: ties to Schlick and Carnap's '**structuralism**' (Richardson 1998; Gower 2000; Neuber 2013).
- Literature on Cassirer and quantum mechanics: continuation of the '**structuralism**' of his earlier monographs (Cei and French 2009; French 2014, sec. 4.8; Ryckman 2015, 2018, 2021).

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Cassirer approaches quantum mechanics against the background of a ***revised* image of classical physics** (irreversibility and statistical mechanics $\implies$ Exner and his circle)

- Cassirer's convergence with Vienna indeterminism is the most striking aspect of *Determinismus und Indeterminismus*.
- Cassirer appropriated most key elements of Vienna indeterminism in pursuit, in parallel, of a very different agenda.

  - Viennese: Quantum mechanics undermines principle of **causality** in physics
  - Cassirer: Quantum mechanics undermines the notion of **substantiality** in physics.

One should speak of a sort of parallel convergence

GÖTEBORGS HÖGSKOLAS ÅRSSKRIFT XLII
1936: 3.

DETERMINISMUS UND
INDETERMINISMUS IN DER
MODERNEN PHYSIK

HISTORISCHE UND SYSTEMATISCHE
STUDIEN ZUM KAUSALPROBLEM

VON

ERNST CASSIRER

"Renouveler la notion de cause, c'est
transformer la pensée humaine".
                                    Taine.

GÖTEBORG 1937
ELANDERS BOKTRYCKERI AKTIEBOLAG

- **Causality**: Laplace-Du Bois-Reymond (predictability) vs. Helmholtz (legality)

  - Cassirer's appropriation of Exner's **indeterminism**
  - Cassirer's endorsement of von Mises and the **frequency** interpretation of probability
  - Cassirer's defense of the Frank/von Mises statistical interpretation of the **uncertainty** relations

- **Substantiality**: the conception of particles as individual substances bearing properties

Part I

Causality: Laplace vs. Helmholtz

Causality: Laplace vs. Helmholtz

- **Du Bois-Reymond** (1872): causality as complete <u>predictability</u> (<u>Laplace Demon</u>)

    - <u>initial state</u> (q_0 and p_0 at t_0) with arbitrary accuracy the using the <u>laws</u> of <u>classical mechanics</u> ($H(p, q)$) predict the <u>final state</u> with arbitrary accuracy (q_t and p_t at any t) with the same precision.

- **Helmholtz** (1878): causality as complete <u>lawlikeness</u> (Helmholtz 1879)

    - the causality principle is a <u>maxim</u>, an imperative to <u>search</u> ever more general '<u>laws</u>', never abandon the search for increasingly more general and comprehensive 'laws' (DI, 78).

> This form of *searching* [. . .] is the decisive factor, and only through this direction of searching can something like causality or natural lawfulness be found. 'Causality' is thus a **regulative principle**

(ECN, VP4181)

Causality: Laplace vs. Helmholtz

Causality as a regulative principle:

- **Schlick** (1931): 'demand' to search for <u>predictive laws</u> but not a 'postulate', that is, a rule to which we must <u>always</u> adhere.
- **Popper** (1934): postulate to <u>never</u> abandon the search for <u>dynamical laws</u>[*]
- **Cassirer** (1936): postulate to <u>never</u> abandon the search for <u>laws in general</u>, be they dynamical or statistical.

> " The inherent, essential characteristic of causality consists in the general requirement of order according to law, not in instructions as to how this order can be discovered and followed through in detail. "

(DI, 203)

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[*]see Cassirer's comment on Popper: ECN, Vol. 4, 184.

Part II

Cassirer's Appropriation of Vienna Indeterminism

Boltzmann's revolution (dualism between statistical and dynamical laws) was an 'unfinished revolution'

- Planck (1914): microscopic phenomena appear to be regulated by statistical laws, due to uncertainty of initial conditions.

  - fundamental laws are **dynamical**

- Exner (1919): macroscopic phenomena appear to be regulated by dynamical laws is the consequence of the 'law of large numbers'

  - fundamental laws are **statistical**

" [. . .] the attempt made by Franz Exner in his *Vorlesungen über die physikalischen Grundlagen der Naturwissenschaften* (1919) [. . .] is of special significance in the development of recent quantum mechanics, inasmuch as Schrödinger in his inaugural address in Zürich in 1922 formulated his own basic view with reference to it "

(DI, 99)

Cassirer's Appropriation of Vienna Indeterminism

" Exner's attempt to formulate anew the concept of natural law contains a speculative or, better, a purely methodological characteristic. Exner did not lean on new empirical facts; [. . .] What moved Exner was, above all, his interest in reason, which caused him to object to the indissoluble dualism of dynamic and statistical laws. A way out of this dualism did not seem to be available so long as one held to the current view, so long as one regarded dynamic laws as the proper and indispensable foundation of all genuine scientific knowledge. For it seemed impossible to carry through the idea that statistical laws can be viewed as merely provisional ones, replaceable later by laws of dynamics. [. . .] Therefore if unity was again to be secured, it could be so only by reversing the procedure: statistical law must be regarded as the comprehensive genus, a concept of *higher order* [*überordnet*] than that of dynamic laws and including them as a special case. This was the thesis advocated and defended by Exner in a new and original way. "

(DI, 101)

Part III

**Von Mises and the Frequency Interpretation
of Probability**

Von Mises and the Frequency Interpretation of Probability

> " It seems to me that of the modern theorists of probability von Mises
> has offered the simplest and most consistent solution. Mises bases
> his theory on the concept of the collective, which he defines by
> definite axiomatic requirements. "

(DI, 117)

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- a **collective** (*Kollektiv*) is an infinite sequence of repeatable, identical experiments or trials (the limit axiom and the randomness axiom)
- **relative frequency** is the proportion of occurrences of an event within a finite collective
- probability as the **limit of the relative frequency** of an event within an infinite collective.

Von Mises and the Frequency Interpretation of Probability

the frequency interpretation shows that the distinction between deterministic and statistical laws as a **gradual** one:

- each physical measurement, say, q and p values, is a repeatable event belonging to a 'collective'.
- a collective is described by a 'distribution' of probabilities over different q- and p-values.
- from the distribution, one can derive its 'mean' and 'dispersion' (a measure of the spread of values) (Mises 1928, 113).

Classical physics makes the *assumption* that if the conditions of the experiment could be fixed without dispersion

- Planck (1914)'s '**Berlin determinism**': the statistical 'dispersion' of the measurement of initial conditions as no lower-bound: fundamental laws are dynamical

- Exner's (1919) '**Vienna indeterminism**': the statistical 'dispersion' of the measurement of initial conditions as no lower-bound fundamental laws are stastical

> Dynamical laws are a special case of statistical laws in which q_0, p_0 form a **'dispersion-free' collective**, where the 'mean value' equals the 'true value'.

> " If one wishes, as von Kries did, to differentiate the two types of laws which are thus obtained as 'nomological' and 'ontological' laws, it becomes clear that the two nowhere contradict each other, that no factual or methodological conflict exists between them. The only requirement which restricts the probability approach, [...], is that this approach must be nomologically permissible—that is, not contrary to a known law of nature. The characteristic difference between probability laws and dynamic laws nevertheless persists, but on the other hand it becomes clear how the two interweave and how only in this way the universal form of 'lawlikeness' in general [*Gesetzlichkeit überhaupt*] arises. "

(DI, 131)

Von Mises and the Frequency Interpretation of Probability

- the 'empiricist' **Schlick**: von Kries' *Kantian* **range interpretation** of probability; statistical laws are not laws; there can only be strict dynamical laws and total lawlessness in the initial conditions
- the 'Kantian' **Cassirer**: von Mises' *postivistic* **frequency** notion of probability: statistical laws not only laws in a proper sense, but the most comprehensive genus of laws

⬇

> the representation of the large finite by the infinite collective is as legitimate as any **idealization**, like the ideal gas or the inextensible thread

" When von Mises explains a collective as [. . .] an extended sequence
of individual observations appearing to justify the assumption that
the relative frequency [. . .] tends toward a definite limiting value,
he is emphasizing that such a collective is not an empirical object
but an idealized conception similar to that of the sphere in geom-
etry or of the rigid body in mechanics [. . .] A collective as such
contains no inaccuracy within itself; rather, it consists of a series
of intrinsically exact observations. In any case, statistics can only
begin where univocal and precise observations are available. It is
true that concrete statistics never lead to numerical series appear-
ing immediately and exactly as collectives in the sense of the ideal
concept here indicated; this, however, does not matter. What does
matter is solely the discovery of those applications of probability
theory based on this concept that are possible in the realm of em-
pirical events.

"

Part IV

Beyond Vienna Indeterminism: Cassirer and Quantum Mechanics

quantum mechanics (**uncertainty relations**) = confirmation Exner's speculation that it might be impossible *in principle* to prepare dispersion-free collectives:

- rejection of Heisenberg's disturbance interpretation of the uncertainty relations: limitations in measurement precision, to errors in simultaneous measurements of q and p on an *individual* system
- defense of the so-called statistical interpretation (Frank 1932, 176–191; Mises 1930, 153, 1934, 149, 1936, 254–262): the uncertainty relations refer to statistical dispersions in measurements on a *collective* of identically prepared systems.

⬇

> the uncertainty relations claim that the product of the **dispersions** $\Delta q \Delta p$ cannot both be reduced below a fixed limit, Planck's h divided by 4π.

The **impossibility of homogeneous, dispersion-free collectives**
follows from the quantum formalism alone, without invoking 'inaccurate'
measurements due to instrument interaction:

- quantum mechanics does not imply sloppy laws (*schlampig*) of nature
  governing individual particles (Sommerfeld).

    - measurement inaccuracy presupposes knowledge of a 'true' value, we
      access only the 'mean' or 'expected' value over a 'collective' of repeated
      measurements.

- quantum mechanics implies strict laws governing collectives rather
  than individual.

    - In classical mechanics, collectives can in principle be dispersion-free,
      whereas in quantum mechanics they cannot be so in principle.

"

One can refer to a basic lack of precision in the statements of quantum theory only so long as one presupposes that statistical statements are necessarily 'inexact' statements. In reality they are strict statements referring, however, not to an individual thing or event but to definite collectives. [. . .][E.g. predictions about the time of decay of atoms are] precise conclusions, even though they say nothing about the fate of the individual atom and the precise instant of its decomposition. There is here no thought of relinquishing causality, for causality in principle has nothing to do with 'fate' but simply and solely with law. Thus in quantum theory also this problem should be understood exclusively in this, its solely 'critical' sense. [. . .] But a real indeterminism, truly worthy of the name, [. . .] instead of being leveled at the determinateness of the individual event, is leveled at the determinateness of the laws which we consider as governing the event.

"

Eddington: statistical laws = 'paper money' — dynamical laws = 'gold standard':

- most physicists are beginning to concede, as Exner surmised, that there is only **paper money** and accept the new monetary system (no dispersion-free states).
- conservative physicists, like Einstein, fear inflation and insist on a return to the **gold standard**, searching for additional hypothetical variables (dispersion-free states)

Convergence Cassirer/Vienna Indeterminism

- Exner's (1919) thesis of the fundamentality statistical law,
- von Mises's (1928) frequentist interpretation of probability,
- Frank's (1932) and von Mises's (1930, 1934) statistical interpretation of the uncertainty relations

Viennese: **causality**   Cassirer: **substantiality**

crisis of '**corpuscularism**' rather than 'determinism' following (Laue 1932, 1933, 1934; Schrödinger 1934; Langevin 1931, 1934).

The problem of individuality in classical physics

- **particle theory of matter**: the 'particle'-picture of matter emerged to assure the identifiability of the parts of a homogeneous medium over time

    - Hertz: the 'material point' is *defined* as the possibility of identification over time

- **field theory of matter**: the electromagnetic field is not an aggregate of material points. We may, and must, indeed, speak of parts of the field; but these parts have no separate existence:

    - Weyl: one cannot identify the *same* electron over time

The problem of individuality in quantum physics

- **Matrix mechanics**: particles, but no trajectories: the classical Fourier series was replaced with what was identified as a matrix of coefficients, whose magnitudes represented the intensity of atomic spectra
- **Wave mechanics**: waves, but no particles: $e|\psi(q)|^2$ represents the charge density of the electron at the point q (e is the total charge of the electron).
- Born's (1926a,b) **probabilistic interpretation**: only particles, no waves: $|\psi(q)|^2$ presente the probability (or relative frequency) an electron will be found at a given place or state of motion.

“ From this, Born concluded that we can continue to [speak] of point-like particles (electrons or protons), but he immediately adds that in many cases these corpuscles cannot be "identified as individuals at all" [(Born 1927, 240)]. ”

" However, what a corpuscle still is after it can no longer be identified as an individual is very hard to say. [In] the statistical approach [. . .] we can no longer maintain and fulfill the demand for *individualization and identification* in the same way that appears possible for macroscopic objects. For statistical statements are, in themselves, strict statements, which apply, however, to collectives and not to individual cases [. . .] If quantum mechanics demonstrates that the possibility of determination does not reach beyond these collectives, then every means is lacking for going further and postulating the existence of an isolated particle. Therefore the statistical character of the premises of quantum theory must not be viewed in an exclusively negative way. It does not state that we are uncertain about location and momentum, *about the path and the entire 'fate' of the individual electron* [. . .][.] It intends to assert that it now considers as its ultimate goal not the determination of individual events but the determination of whole *systems* of events. "

(DI, 230 sq.)

- All measurements presuppose collectives: because of the **uncertainty relations** no physical method exists to obtain homogeneous, dispersion-free q and p-collectives

  - the notion of well-defined 'trajectory' of individual identical particles loses its "empirical reality" (DI, 223).

- In the case of systems containing multiple non-interacting identical particles, **non-classical statistics** replace the old Maxwell-Boltzmann statistics:

  - particles do not even act as separate and distinct parts of the system as a whole; they cannot even be 'labeled' as particle 1 and particle 2.

wave-picture inadequate — particle-picture inadequate

> We must face squarely the new problems thus created. There seems to be no return to the lost paradise of classical concepts; physics has to undertake the construction of a new methodological path. I do not wish to claim at all that the end of this path is already clearly in sight. But the direction in which the solution is to be found seems to me clearly recognizable. [...] If it appears that certain concepts, such as those of position, of velocity, or of the mass of an individual electron can no longer be filled with a definite empirical content, we have to exclude them from the theoretical system of physics, important and fruitful though their function may have been.

- **Bohr, Heisenberg, and Born**: no one will expel us from the 'paradise of classical concepts'. The latter are indispensable for describing the results of experiments involving quantum phenomena, despite the impossibility of their simultaneous applicability: either waves or particles.
- **Laue and Schrödinger**: quantum mechanics has forced us out of the classical Eden to which there is no return: Classical concepts, the pictorial models of older physics, might turn out to be dispensable and should possibly be replaced by something more adequate: neither waves nor particles

$$\Downarrow$$

❝ "[t]he concept of the mass point seems to face such a necessity of reorientation" (DI, 245).

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Part V

Conclusion

Conclusion

Cassirer/Vienna convergence: collectives can be regarded as ideal objects that can figure in strict laws

- **Viennese**: the impossibility of dispersion-free collectives $\Longrightarrow$ notion of causality that dominated classical physics.
- **Cassirer**: the impossibility of dispersion-free collectives $\Longrightarrow$ the trans-temporal individuality of particles independent of all possessed 'properties'.

$\Downarrow$

> " The essential problems posed by quantum mechanics for epistemology thus lie at a different point. They deal primarily not with the category of cause and effect but with the category [...] of substance and accident. "

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(DI, 235)

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Conclusion

- **Weizsäcker (1937)** accuses Cassirer of having conceded too much to his opponents and prefers Hermann (1935)'s form of 'Kantianism'.
- **Frank (1938)** prefers Cassirer as 'disintegrating' [*zersetzend*] concept of causality to Hermann's.

" It is true that the scientist does not give us a logical or empirical proof of this fundamental assumption. The only proof that he gives us is his work "

Cassirer 1944, 219

Thanks!

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