Translation of three short papers by Grete Hermann

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After a number of years of relative neglect, it is now becoming apparent that Grete Hermann (1901-1984) was one of the most accomplished neo-Kantian philosophers of the last century – in part thanks to the recent publication of two volumes on and of her work, one in English (Crull and Bacciagaluppi 2017) and one in German (Herrmann 2019), both reviewed in this issue. The latter in particular contains Hermann's entire output on modern physics and philosophy of science.

Below I translate the three shortest papers by Hermann in that volume, which I introduce here. They provide quick but fascinating glimpses into some of Hermann's ideas on philosophy of science, quantum mechanics, and transcendental idealism. They are: from 1935 a book review of Popper's *Logik der Forschung* [the original German edition of the *Logic of scientific discovery*], from 1936 a comment on Schlick's posthumously published talk 'Quantentheorie und Erkennbarkeit der Natur' ['Quantum Theory and Knowability of Nature'], and from 1937 a short summary of Hermann's ideas on the relation between Kant's philosophy and modern physics (specifically electrodynamics, the special and general theories of relativity, and quantum mechanics) presented at the Congrès Descartes in Paris.[1]

1 Popper review

Popper had published *Logik der Forschung* in late 1934 (with the impressum of the following year) (Popper 1935). The physics journal *Physikalische Zeitschrift* had originally commissioned a review from Carl Friedrich von Weizsäcker, who had however declined and recommended Hermann instead, because he had just been involved in a controversy with Popper in the pages of *Die Naturwissenschaften* (Popper and Weizsäcker 1934). Weizsäcker had pointed out a technical error in an ill-fated attempt by Popper to show the incompleteness of quantum mechanics. A thought experiment was supposed to allow one to reconstruct both the position and the momentum of one particle by appropriate measurements on another particle that had collided with it (but without being able to select *which* particle of an ensemble had these precise values). Thus – much like EPR the following year (Einstein, Podolsky and Rosen 1935) – Popper wanted to show that quantum mechanics was correct (because ensembles violating the uncertainty relations could *not* be prepared) but incomplete (because individual particles within these ensembles *had* precise values of position and momentum).[2]

Hermann singles out two elements that play a crucial role in Popper's philosophy of science: Popper's falsificationism (which she summarises with some sensitivity) and his notion of the theory-ladenness of observation – both approvingly. Indeed, Hermann is firmly committed to the idea that there are no pure observations. But, as a Kantian, she believes inherent theoretical elements to be *a priori*, and rejects Popper's idea that basic statements are stipulations, which for her debases science 'to a blind play of dogmatic whimsy'.

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[1] Herrmann (2019, pp. 269–271, 273–274 and 379–381, respectively). Translations in this introduction are mine and all emphases within them are original.

[2] Popper discussed this thought experiment also in *Logik der Forschung* (Popper 1935, Appendices VI and VII). For further details, see e.g. Frappier (2017) and Bacciagaluppi and Crull (2021, Section 1.4, esp. 1.4.4). For related correspondence between Hermann and Weizsäcker, see Letters 14 and 15 (as well as 21) in Herrmann (2019).

Hermann then goes on to criticise what she describes as Popper's 'only example treated in detail – the interpretation of Heisenberg's uncertainty relations'. She does not summarise the controversy between Popper and Weizsäcker, but identifies the reason for Popper's mistake as being his reliance on the probabilistic interpretation of quantum mechanical wave functions as relating to *ensembles* of systems. (Indeed, the ensemble interpretation of probability pervades the entire *Logik der Forschung*.[3])

What Popper neglects, according to Hermann, is that this interpretation of wave functions as providing statistical descriptions of ensembles stands in a complementary relationship to their use as providing state descriptions of individual systems, which are thereby also subject to the uncertainty relations. These comments shed light also on her own views on quantum mechanics, because this is the first place where she explicitly talks of the complementarity between these two aspects of the quantum mechanical description.

2 Comment on Schlick

Schlick's talk on 'Quantentheorie and Erkennbarkeit der Natur' (Schlick 1936) was his contribution to the Second International Congress on the Unity of Science, devoted to 'The Problem of Causality'. It was held in Copenhagen 21–26 June 1936, under the presiding genius of Niels Bohr among others. Schlick, however, was not present when his talk was read to the congress – in fact he had been murdered in Vienna on 22 June.

The talk itself argues very lucidly that the limitations on the possibility of knowledge that are imposed by quantum mechanics are not subjective limitations in the sense that there should remain something unknown but unknowable – as arguably for Kant the knowledge of things in themselves. 'The limit of knowability is at the same time the limit of law-likeness in nature' (Schlick 1936, p. 319). Measurement does not disturb already existing features of physical systems, nor does it force these to acquire such features. We observe only measurement results, and claims that a system has some position or momentum when these quantities are 'indeterminate' are strictly meaningless (*ibid.*, pp. 321–322).

Similarly, Schlick wishes to establish that, insofar as the limitations imposed by quantum mechanics suggest also limitations for knowability in other parts of nature, e.g. the life sciences, these are again limitations on what there *is* to be known. They do not leave room for, say, 'the so-called freedom of the will or the assumption of spiritual substances' (p. 317), or the idea that 'a full knowledge of *life* processes might perhaps remain precluded to us because the precise observations required for such knowledge would disturb the life processes themselves' (p. 323).

Schlick is keen to establish in particular that the latter is not what Niels Bohr is suggesting with his ('truly deep') remarks about life (p. 318). Rather, so Schlick, Bohr's remarks should be interpreted in the following sense. Even though physical (indeed classical) concepts are indispensable in describing results of observations, we may expect *any* physical concepts to prove inadequate in the description of life processes, just as *classical* concepts have proved inadequate in the description of physical processes (p. 326).

Hermann appreciated Schlick's paper, which according to her 'was the best that was presented at this congress from the positivist side',[4] but not its criticism of Kant – including the implicit criticism of

[3] It was only in the 1950s that Popper was to propose his interpretation of singular probabilities as propensities, a notion that appears repeatedly in the added footnotes and appendices in *The logic of scientific discovery* (Popper 1959).

[4] Grete Hermann to Heinrich Scholtz and Adolf Kratzer, 8 July 1936 (Herrmann 2019, Letter 28).

causality. She took her comment as the opportunity to clarify these issues based on her own work on quantum mechanics and on transcendental idealism.

Hermann points out the apparent tensions among some of the features of quantum mechanics discussed by Schlick, and claims that these get resolved if one understands quantum mechanical descriptions as *relative to a context of observation*. This is Hermann's central interpretational move, and the one that reconciles Kant and quantum mechanics.

Indeed, for Hermann, Bohr's indispensability of classical concepts is the same as the necessity of Kant's *a priori* notions. But – in what is in fact a Friesian element – she understands the criteria of application of Kant's notions to be a matter open to empirical investigation. The lesson of quantum mechanics is that classical notions can be applied (within the limits of the uncertainty relations) only relative to observational contexts, and not in the passage between one context and the next. In this sense, the limits of knowledge discussed by Kant turn out to *agree* with those imposed by quantum mechanics. In particular, the principle of causality is vindicated, because it finds strict application *within* each observational context.[5]

Hermann does not give the details of her arguments here – referring instead to her main essay on quantum mechanics, 'Die naturphilosophischen Grundlagen der Quantenmechanik' (Herrmann 2019, pp. 205–258) ['Natural-philosophical Foundations of Quantum Mechanics' (Crull and Bacciagaluppi 2017, pp. 239–278)]. But she makes a noteworthy if passing remark about the apparent 'collapse' of the wave function: it is not a real physical process, because among other things it would have to propagate *faster than light*. This is a criticism of collapse that tends to be missing from the writings of other proponents of 'Copenhagen' views like Bohr or Heisenberg.[6]

3 Congrès Descartes

Hermann was clearly interested in the dialogue with the logical positivists. In particular, besides her participation in the Unity of Science congress and active contacts with the Berlin Circle,[7] Hermann was busy organising a meeting in Heidelberg for September 1936, where major approaches to the theory of knowledge were to have been presented by herself, by Schlick and by the prominent logicist Heinrich Scholz. While the meeting took place on a smaller scale (in particular without Schlick), Hermann presented her results there, and published them in 1937 as 'Über die Grundlagen physikalischer Aussagen in den älteren und den modernen Theorien' ['On the Foundations of Physical Statements in the Older and the Modern Theories'] (Herrmann 2019, pp. 275–334), which is the most detailed statement of her position in natural philosophy. It is unclear whether Hermann attended the Third Congress in Paris at the end of July 1937 (Otto Neurath had invited her on 10 June, see again the catalogue of Hermann's *Nachlass*), but she appears to have organised a small private philosophy meeting there a few days later, as a follow-up to the Heidelberg meeting.[8] Between the Third Congress and that meeting (if it took place),

[5] For more on Hermann's neo-Kantianism, see Paparo (2017), Crull (2017) and Cuffaro (2020), as well as Bacciagaluppi (in preparation a).
[6] This criticism is spelled out in more detail in Hermann's own discussion of the EPR paper (and was perhaps prompted by it). See again her letter to Scholtz and Kratzer of two weeks later (Herrmann 2019, Letter 28), as well as Bacciagaluppi (in preparation b).
[7] Cf. Milkov (2008, p. 57), who cites Danneberg and Schernus (1994, pp. 396–397, fn 26). There is further a report in the *Deutsche Allgemeine Zeitung* of 1 February 1935 of a talk by Hermann for the Berlin Circle on 'Korrektur des Kausalprinzips' ['Correction to the Causality Principle'] (see the catalogue of Hermann's *Nachlass* in the Archiv der sozialen Demokratie, Bad Godesberg).
[8] Cf. Letters 33 and 38 in Herrmann (2019).

Hermann also presented her position at the Ninth International Congress of Philosophy (Congrès Descartes). The brief published contribution to the proceedings is the third paper translated here.

The position Hermann summarises is an extension of her work on quantum mechanics. She had first provided an analysis of special and general relativity in another essay, 'Die Bedeutung der modernen Physik für die Theorie der Erkenntnis' ['The Significance of Modern Physics for the Theory of Knowledge'] (Herrmann 2019, pp. 325–377), which was awarded a prize from the Saxon Academy of Sciences on the same fateful 22 June 1936. There she argued that while formally special and general relativity could provide an absolute description in terms of Minkowskian manifolds, the bridge between the formalism and the data of perception was provided by the intuitions of space and time applied in each (global or local) inertial system. In 'Über die Grundlagen physikalischer Aussagen...' she then extended the analysis further, starting from a (Friesian) analysis of the theoretical elements with which we organise our everyday experience – and noting that they closely match the mechanical world picture of classical physics – then examining where electrodynamics, relativity and quantum mechanics appear to depart from them, and arguing that in fact they do not.[9]

Hermann's conclusion is that, where modern physics departs from classical physics, it is always and only by relinquishing the assumption that in the attempt to connect the data of perception into a body of physical knowledge, the Kantian notions can be applied uniformly across all contexts of observation. She presents this as fitting into a reading of transcendental idealism along the lines of the neo-Kantianism of Fries and her own teacher Nelson: the *a priori* principles apply only to the objects of our finite observations, which 'cut' through the fundamentally unintuitive structure of relations described by physics. This, however, glosses over the novelty of Hermann's approach in which the criteria of application of the principles may depend crucially on the different contexts – ensuring objectivity but not at the price of absolutism.

After the war, Hermann was to direct her main efforts towards the reconstruction of Germany's education system, but she continued to work on her revised understanding of transcendental idealism and its repercussions not only for natural philosophy but also for the debates on life, free will, and ethical and political responsibility.

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Review of: K. Popper, *Logik der Forschung. Zur Erkenntnistheorie der modernen Naturwissenschaft*. Octavo. vi+248 pp. Berlin 1935. Julius Springer. Sewn. Reichsmark 13.50[10]

Grete Hermann

Popper wishes to set up the 'rules of the game "empirical science"' (p. 22) ['rules of the game of empirical science', p. 32].[11] In fact, what he offers as the pattern of scientific research is nothing but a game with statements that, if anything, express only prejudices. The interest lies not in this outcome, but in the path that leads to it.

Indeed, Popper's constructions are based on two thoughts that are undoubtedly correct and significant for natural philosophy – largely leaning on positivist lines of reasoning, but in some places pursuing these uncommonly far to their extreme consequences. The first one: testing and justification of physical hypotheses never aims for an absolute and definitive foundation (verification); it rather exposes the stated claims to the possibility of being refuted (falsified) by contrary facts, abandons them in the case of such refutation, and otherwise retains them as corroborated, but always with the right to retract them or to make refining corrections (p. 6f) [p. 10].

This is combined with the second observation: there is no statement of experience, as simple and primitive a claim as it may be, that in this sense is not already application of a theory and thereby shares its character of being at most a well corroborated hypothesis. For even the simplest general concepts under which we subsume the objects around us include aspects of law-like behaviour (p. 52f) [p. 76]; therefore their application goes already beyond the mere findings of perception.

On the basis of these considerations Popper builds his edifice of definitions and methodological prescriptions: empirical science is defined as a system of statements to which only the requirement of testability through experience applies (falsifiability), not that of rigorous foundation (p. 12f) [p. 18]. The question of a criterion for the degree of this testability is discussed in detail.

Already this definition bears rich fruit for natural philosophy. Since the testing of general physical statements consists only in checking the occurrence of particular statements – predictions – drawn from them, for Popper all the difficulties disappear that are connected with the attempt to found general statements of experience: the problems of induction and of causality are eliminated.

But further: since also the singular statements of experience – the basic statements that bring about failure or corroboration of theories – enter the investigations only as applications of theoretical posits, in the end failure or corroboration of theories is brought about by other theories that already count as corroborated. (In particular, a theory can be refuted by a singular statement only when this refutation takes place in the framework of a refuting theory that is itself corroborated by the singular statement, p. 47 [p. 66].) But now, where should the chain of theories end that corroborate or refute one another? Popper prescribes: there may be no limits to *testability*; but since testing must stop somewhere, and since the basic statements to which it stretches are as little capable of rigorous foundation as other statements of experience, it shall be left to the researcher to decide on their acceptance, in a way that can be explained by the experiences that have convinced them, but is unjustified and unjustifiable. These

[10] Translated by Guido Bacciagaluppi (g.bacciagaluppi@uu.nl), from the reprint in Kay Herrmann (ed.), *Grete Henry-Hermann: Philosophie – Mathematik – Quantenmechanik* (Springer, 2019), pp. 269–271. Originally published in German in *Physikalische Zeitschrift* **36**(13), 481–481 (1935). Thanks to the editors for a careful reading of the translation.

[11] *Translator's note*: Where Hermann gives page references or quotations from *Logik der Forschung*, I add in square brackets the corresponding page references or quotations from *The logic of scientific discovery* (in the 2002 Routledge Classics edition).

basic statements, which decide on the corroboration or failure of physical theories, are '*from a logical point of view arbitrary stipulations*' (p. 65) ['from the logical point of view, accepted by an act, by a free decision', p. 92].[12]

Popper has again freed himself in one stroke from a whole knot of problems in natural philosophy – from all those that concern the cognitive character of perception and the possibility of founding empirical judgements in perception. At the same time it becomes clear what price he pays for this release from natural-philosophical difficulties: through definitions he has first curtailed the claim to truth of the empirical sciences, then completely thrown it out of the study of nature. The pains of justifying it are clearly gone, but only because science is debased to a blind play of dogmatic whimsy. The comfort offered by Popper, that 'this kind of dogmatism' is 'harmless', because the basic statements accepted through arbitrary stipulation may indeed 'be tested further if the need to do so should arise' (p. 61) ['this kind of dogmatism is innocuous since, should the need arise, these statements can easily be tested further', p. 87] is unable to cast a more favourable light on this outcome. Arbitrariness is not reduced by removing it step by step to ever different places.

The two crucial thoughts mentioned at the beginning, which are the starting point for Popper's considerations, hold true. They have always presented difficulties and problems for the interpretation of physical research in terms of natural philosophy. They must be confronted by those who ask of scientific claims the Kantian question 'Quid juris?'. Popper asks this question (p. 4) [p. 7]; but he forgets to account to himself or the reader what the claim to knowledge is in fact directed towards. Thus for him the question: Quid juris? shifts furtively to the other question: How should this claim to knowledge be constituted in order to blend as smoothly as possibly with the two mentioned characteristics of science? Understandedly, the easiest solution is to eliminate such a claim to knowledge completely. But this observation has nothing to do with justifying physics' claim to knowledge.

Quite as to illustrate how Popper's considerations fall beside the point of the problems raised by physics, the only example treated in detail – the interpretation of Heisenberg's uncertainty relations – is based on a misunderstanding of quantum mechanics. The physical mistake in the crucial thought experiment – which is supposed to show the possibility of predicting under appropriate conditions the position and momentum of an electron with a precision exceeding the uncertainty relations – has already been clarified in Popper's controversy with Weizsäcker (*Naturwissenschaften* **22**, issue 48 of 30 November 1934). The more detailed treatment of quantum mechanics that Popper gives in his book reveals the reason for this mistake. Popper lets himself be misled by the probabilistic interpretation of the wave functions into applying these quantum mechanical state descriptions (and the uncertainty relations they lead to) only to ensembles of physical systems – according to the procedure in probability theory of translating statements about probabilities into statements about relative frequencies. He thus does not presuppose that an appropriately selected individual system must respect the uncertainty relations. In this he neglects that the duality experiments force one to apply features of the particle picture as well as of the wave picture already to individual systems, but thereby also to limit the applicability of the two pictures in accordance with the uncertainty relations. How these two sides of the quantum mechanical formalism – on the one hand the probabilistic interpretation of the wave function, on the other its utilisability as a state description of an individual physical system – are to be reconciled is a physical problem that is solved by Bohr's doctrine of complementarity, but cannot be eliminated through a one-sided limitation to the probabilistic approach.

[12] *Translator's note*: The original emphasis and wording in Popper is 'logisch betrachtet, *willkürliche Festsetzungen*'.

Comment on Schlick[13]

Grete Hermann

The problem of natural philosophy raised by quantum mechanics can be characterised with two pairs of statements that have featured in Schlick's discussion but without Schlick having highlighted, let alone resolved, the contradiction that seems present between the propositions of each pair:

(1a) The uncertainty relations do not represent merely subjective limits to possible observations, in the sense that there should be real features of a physical system that are unobservable. Rather, an atomic system *has* no simultaneously sharp position and momentum.

(1b) Nevertheless, the replacement of a state description of a system, which is to be performed based on a measurement – say of a wave function that is 'spread out' over the whole of space – through another one – say a wave function with exact specification of position –, cannot be understood as specifying a real physical process in space in which a wave extended over the whole of space 'shrinks' to a wave packet concentrated within a small range of positions. (A notion which, apart from other physical absurdities, would include the assumption of processes propagating superluminally.)

Similarly the contrast in the other pair of claims:

(2a) The intuitive conceptions of classical physics prove inadequate to the task of a fully quantum mechanical description of a physical system.

(2b) Nevertheless, according to Bohr's correspondence principle, also in quantum mechanics every single step from an observation to how it is put to use in the physical formalism, and *vice versa* from a formula derived in the formalism to the corresponding prediction of an observation, can and must be interpreted entirely using the classical-intuitive conceptions.

The seamless reconciliation of the respective (a) and (b) is possible only by supposing that the quantum mechanical state description of a physical system – as opposed to the state description in classical physics – does not pretend to characterise the physical system uniquely and adequately, but only relative to the context of observation then present, and that it changes with the latter.

Thereby however, as shown by more detailed considerations, the opposition disappears that Schlick claims between the limitations of knowledge demonstrated by Kant in his doctrine of transcendental idealism and the limits of natural description that quantum mechanics forces us to recognise – at least insofar as one takes into account the corrections brought by Fries and Nelson to the formulation and justification of this doctrine. It becomes equally manifest that quantum mechanics has in truth not brought about the alleged refutation of the *a priori* principles of natural philosophy postulated by Kant, in particular of the law of causality. Rather, quantum mechanics revises the usual version of the principle of causality only insofar as it separates it from the assumption often conjoined with it that physics must lead to a unique adequate description of nature. It otherwise upholds the presupposition of seamless causal connections. (To justify these claims, I can here merely refer to my essay 'Die naturphilosophischen Grundlagen der Quantenmechanik' ['The natural-philosophical foundations of quantum mechanics'], *Abhandlungen der Fries'schen Schule*, vol. VI, issue 2, Sections 9, 12, 16–18.)

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[13] Translated by Guido Bacciagaluppi (g.bacciagaluppi@uu.nl), from the reprint in Kay Herrmann (ed.), *Grete Henry-Hermann: Philosophie – Mathematik – Quantenmechanik* (Springer, 2019), pp. 273–274. Originally published in German as 'Zum Vortrag Schlicks' ['On Schlick's Talk'], *Erkenntnis* **6**(5/6), 342–343 (1936). Thanks to the editors for a careful reading of the translation.

The significance for natural philosophy of the move from classical to modern physics[14]

Grete Hermann

SUMMARY – This study shows how, despite the changes it has introduced, modern physics preserves certain fundamental ideas of classical physics (Bohr's correspondence principle). While it gives up much of the ideal of a mechanistic physics, it still remains tied to Kant's thesis that the forms of intuition and the categories are the necessary presuppositions for the knowledge of nature.

1. The development of modern physics has two distinctive aspects: on the one hand the demand for a revision of almost all fundamental assumptions on which the knowledge of nature has been based until now, and indeed for a *revision based on experience*; on the other hand the upholding of certain fundamental conceptions of classical physics, which finds its strongest expression in Bohr's *correspondence principle*. Modern physics presents us with the problem within natural philosophy of reconciling these two aspects.

2. The dualism between the wave and particle picture in quantum mechanics, with its consequences for [our] causal command of natural phenomena represents the strongest departure from the classical picture of nature. But this departure is closely connected to a series of earlier transformations in the picture of nature. The first step in this direction is taken in Maxwell's theory, which detaches the wave picture from the presupposition of a material support until then taken for granted. A further stage is the theory of relativity, with the demonstration that one cannot ascribe to matter a definite state of motion with respect to the 'ether'. Finally, while the steps up to now have brought the wave and particle picture more and more into opposition, quantum mechanics leads one to applying them again to one and the same atomic process.

3. The starting point of this development is characterised by the abandonment of an old expectation, which in the Enlightenment dominated research in both physics and natural philosophy, namely the expectation that in the end physics would reduce completely to classical mechanics. What distinguishes this discipline is in fact its intuitive spatiotemporal modelling of natural phenomena. The construction of such a model proceeds by finding *substances* that fill space, determining the *interactions* obtaining between them, and the *causal modifications* of their state of motion thereby brought about. The fundamental concepts in the picture of nature of classical mechanics thus correspond so precisely to the Kantian forms of intuition and categories, that on the one hand Kant's philosophy has been seen as a justification for privileging classical mechanics, and on the other hand the discovery of the limits of classical mechanics has been taken as a refutation of Kant's insights.

4. If one analyses more closely the physical arguments that have led to this discovery, however, it turns out that Kant's fundamental concepts nowhere fail to apply. The experiments that ground the derivation of Maxwell's equations examine the interaction between *material bodies*; measurements of spatial and temporal relations in the theory of relativity presuppose the classical intuitions of *Euclidean space* and of an objective *determination of simultaneity*; quantum mechanics presupposes *causal explanations* in its

[14] Translated by Guido Bacciagaluppi (g.bacciagaluppi@uu.nl), from the reprint in Kay Herrmann (ed.), *Grete Henry-Hermann: Philosophie – Mathematik – Quantenmechanik* (Springer, 2019), pp. 379–381. Originally published in German (with French summary) as 'Die naturphilosophische Bedeutung des Übergangs von der klassischen zur modernen Physik', Chapter XVII in Raymond Bayer (ed.), *Travaux du IX^e Congrès International de Philosophie – Congrès Descartes. Vol. VII, Causalité et Déterminisme*. Actualités Scientifiques et Industrielles, n. 536 (Paris: Hermann et C^ie, 1937), pp. 99–101. Thanks to the editors for a careful reading of the translation.

theory of measurement, also for unpredictable events – indeed it is only by displaying these already known causes that it can establish the futility of a further search for causes, and thus the fundamental significance of the limits set to prediction.

5. In each of these disciplines however – in each case at a different place in the physical picture of nature – one relinquishes an assumption that is straightforwardly satisfied in classical mechanics and was tacitly the basis for the programme of reducing the whole of physics to classical mechanics. It is the assumption that every application of the classical connecting principles can be held on to unambiguously throughout the whole physical interpretation of natural phenomena. According to this assumption, what can be interpreted in some context as a substance, as simultaneous, as equally long, as matter in motion, must be interpreted in the same way in *each* observational context. It is in truth this assumption that has been abandoned beginning with Maxwell's theory and in ever more radical ways in modern physics. This is the explanation for the many natural-philosophical paradoxes that prevent the intuitive interpretation of the results of modern physics.

6. Modern physics thus indeed accords with Kant's thesis that the above-mentioned forms of intuition and categories are necessary preconditions for the knowledge of nature. Instead, the distinctive step that sets physics apart from the picture of nature of classical mechanics rules out any realist interpretation of physics that sees in the picture of nature provided by physics an adequate description of the phenomena. In this sense – when one examines its modes of argumentation closely – modern physics serves the purpose of extending and endorsing another Kantian idea: that of transcendental idealism – in the form given to it by the works of the Friesian school whereby knowledge of nature does not adequately capture reality, but in an imperfect way only extracts relational structures from it, the grounds of which remain undetermined within the framework of this knowledge.