

Saturday, June 26 PM 1:30-4:30, Room 140

Session 3 (room 140): **Philosophy of Quantum Mechanics**

Gregor Schiemann, “Werner Heisenberg’s Position on a Hypothetical Conception of Science as Expressed in his Popular Speeches and Writings”

Melanie Frappier, “Heisenberg’s Changing Perspectives on the Indeterminacy Principle”

Ravi Gomatan, “Complementarity—Did Bohr Miss the Boat?”

Scott Tanona, “Quantum Theory and the Correspondence Principle”

“Werner Heisenberg’s Position on a Hypothetical Conception of Science as Expressed in his Popular Speeches and Writings”

Gregor Schiemann

Werner Heisenberg made an important – and as yet insufficiently researched – contribution to the transformation of the conception of science. This transformation involved a re-assessment of the status of scientific knowledge from certain to merely hypothetical. The beginnings of this process can be traced back to the nineteenth century (i.e. Herschel, Whewell, Helmholtz). Looking at Heisenberg as an example, I would like to investigate the influence of the foundation of quantum mechanics – which shaped his understanding of science – on the relativization of claims to validity. My conjecture is that the concepts of truth and reality in fact played a more decisive role than the concept of probability (cf. Jammer, Mehra, Rechenberg, Darrigol, Beller and others on Heisenberg’s conception of quantum mechanics; c.f. Heelan, Hertz, Chevalley, Beller and others on his epistemology and his ontology of physical knowledge).

Heisenberg’s conception of science underwent a transformation itself and is not free of contradictions. By restricting his matrix mechanics to calculating measurable quantities, Heisenberg initially sought a foundation for quantum mechanics that was as free of hypotheses as possible. Later, unresolved problems about the reality of theoretical entities and about the truth of atomic theories as well as their relation to other physical theories and to the concept of knowledge in the natural sciences – without impugning the formal structure of this foundation – led to a hypotheticization of claims to validity.

In his writings on the history of physics, Heisenberg rejected the putative universality and exclusivity of the traditional concept of truth, as well as the demand that all real entities be susceptible of spatio-temporal and causal description. He opposed the concept of knowledge predominant in physics at the beginning of the twentieth century with his own conception of a limited range of application of single (“closed”) theories. This conception bears a resemblance to those of Kuhn and Quine insofar as it implies that logically inequivalent theories can share the same range of application and can succeed each other historically.

With an eye to Goethe, Heisenberg generalized these elements of a hypothetical conception of science in a pluralist classification of all scientific disciplines. Among the scientific disciplines, Heisenberg distinguished phenomenological from fundamental theories. Whereas one cannot demarcate the range of application of a fundamental theory

with certainty, the empirical data and empirically justified propositions of phenomenological theories are irrefutable.

This absolutist viewpoint runs contrary to his hypothetical conception of science on the empirical level. On the theoretical level, Heisenberg's critique of certain knowledge contradicts his Platonist viewpoint according to which there can be only one fundamentally true theory.

I shall demonstrate that these and other inconsistencies in Heisenberg's conception of science can partially be traced back to the relativization of his own original claims to validity. The inconsistencies arose primarily from the epistemic and orientational uncertainties inherent in the upheaval in which Heisenberg's thinking was enmeshed – namely, the paradigm shift in atomic physical research and the transformation of the conception of science.

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“Heisenberg's Changing Perspectives on the Indeterminacy Principle” Melanie Frappier

Critiques of Werner Heisenberg's interpretation of the uncertainty relation usually focus on Heisenberg's derivation of the principle from the microscope thought experiment without giving much attention to his derivation of the principle from the Dirac-Jordan transformation theory. For Heisenberg, however, the most convincing element of his argument in favour of his interpretation of the uncertainty relation as a limit on possible simultaneous knowledge of conjugate variables was the parallelism he believed existed between these two kinds of derivations. From a modern perspective, this association is shocking since the two arguments suggest two incompatible interpretations of the uncertainty relations. While the derivation from the theory's mathematical formalism leads to a statistical interpretation – which understands the indeterminacy principle as prohibiting the preparation of dispersion-free ensembles - the microscope thought experiment implies a disturbance interpretation which presents the uncertainty principle as a fundamental limit on the precision of simultaneous measurements of conjugate variables performed on a unique quantal system. If this dual justification of the uncertainty relation explains why, today, defenders of both interpretations can correctly claim they are faithful to Heisenberg's original intentions, it does not explain how Heisenberg could have considered the two arguments as being truly complementary.

In this talk, I explore the historical development of Heisenberg's two arguments. I will first show that Heisenberg did not originally conceive the microscope thought experiment as an argument in favour of the uncertainty relations, but rather as a simple illustration of the intrinsic disturbance any measurement produces. However, because he failed to distinguish between measurements and state preparation procedures, because he did not investigate the origins of experimental errors, and because he did not possess a clear definition of the notion of state, Heisenberg soon conceived the microscope thought experiment as complementing his derivation of the uncertainty principle from the

formalism of quantum mechanics. This talk then explores how both the microscope thought experiment and the derivation of the uncertainty principle from the transformation theory evolved between 1926 and 1932, continuously influencing each other, while Heisenberg - helped by Pauli, Dirac, Bohr, and von Weizsacker – struggled with the interpretational difficulties that sprung from the conceptual ambiguities that plagued the initial interpretational debate. This analysis of the early interpretational problems of the uncertainty relation ultimately suggests that most of the disputes over the meaning of the uncertainty relation probably originate from the fact that physicists, misled by the many conceptual difficulties associated with quantum physics, have often conflated different physical relations under the banner of the indeterminacy principle.

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“Complementarity—Did Bohr Miss the Boat?”

Ravi Gomatan

Two principal a-priori commitments inform Bohr’s interpretive writings.

- (A) The Ψ function does not represent a physical object and its evolution, i.e. “there is no quantum world” at the level of formalism.
- (B) Ordinary language words retain all their usual classical meanings at the level of describing the observations (the correspondence principle).

Because of these twin commitments, not only Bohr’s own interpretation treats the wave function instrumentally, it is incompatible with the existence of any realistic interpretation. Indeed, Bohr ruled out the very possibility. Yet, many realist interpretations of the Ψ -function exist, such as the collapse model, many-worlds, and hidden-variables. All of them reject Bohr’s assumption (A) but *retain* (B). However, none of them give the sense that quantum theory has been “understood”; each has its own counter-intuitive feature. In addition, all reproduce the same statistical predictions. Thus, none can be preferred over the others on empirical grounds.

Interestingly, many of Bohr’s interpretive insights recur in these interpretations, suggesting (a) Bohr’s insights may have a more lasting value and import than his interpretation based on them, and (b) that going past Bohr’s interpretation to develop the realist interpretation would require rejecting *both* commitments of Bohr.

Weizsacker has commented, “Bohr’s interpretation has never been fully clarified. It needs an interpretation itself, and only that will be its defense.” In this paper, I identify several of Bohr’s key and essentially correct interpretive insights, including the following: quantum inseparability; wave-particle duality as an apparent dilemma; that within the framework of classical concepts quantum theoretical concepts have only epistemological implications; that uncertainty relations limit simultaneous definability rather than measurability. I separate these insights from his interpretation and argue that Bohr’s version of complementarity is insufficient to explain and apply each of these insights properly to even develop the “wholly epistemological” interpretation he was aiming for.

For example, his insight that wave-particle duality is an apparent dilemma rests on his move that complementarity refers to observations (whereas duality refers to the electron itself). However, complementarity of observations makes no sense unless the observations themselves, not just the experimental arrangements that produce them, are ‘different’ in some essential way. Yet, the observations are always identical, say, spots on the photographic plate. I show how by jettisoning *A and B* we can render ‘difference’ as *the* essential characteristic of complementarity, over ‘mutual exclusivity’.

With this new view of complementarity in place, I develop an alternative Bohr-like interpretation that also treats the formalism instrumentally and features all of his interpretive insights *sans* his ambiguity to explain the current quasi-classical experimental praxis. However, unlike Bohr’s interpretation, it is fully compatible with the existence of an alternative truly realist interpretation (because of jettisoning *both A & B*). In addition, it itself suggests some ideas toward developing such a realist interpretation.

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“Quantum Theory and the Correspondence Principle” Scott Tanona

In this paper I will discuss some different conceptions of the correspondence principle in quantum mechanics. One conception of the correspondence principle is the general idea that a theory that supercedes a previously successful theory ought to recapture the older theory as a special or limiting case. This conception is often attributed to Bohr and has enjoyed some measure of popularity, especially as a proposed heuristic device for the development of new theories and as a characterization of the growth of scientific knowledge.

However, Bohr's own view of the correspondence principle was quite different from this. Bohr thought the correspondence principle was a bridge between theory and empirical phenomena where our description of these phenomena involved classical theory. Bohr argued that we needed to retain classical wave theory to describe independently such phenomena as atomic spectra and that the correspondence principle was needed to associate these phenomena with atomic properties. The principle thus involved the asymptotic agreement between classical and quantum theory, but more importantly concerned how we provide empirical content to a theory when the empirical descriptions are laden with other theory.

After the development of quantum mechanics, the work of the correspondence principle would seem to have been done, at least as a purported tool for the development of theory. But it continued to play a role in the interpretation of theory for both Bohr and Heisenberg, though in different ways. Bohr claimed that quantum mechanics embodied the correspondence principle, since elements of the matrix representation of a property retained the connection the correspondence principle had made between the Fourier representation of electron motion and the properties of emitted radiation even though they no longer could be understood in terms of actual electron motion. Heisenberg had a

somewhat different conception of the correspondence principle, as he thought that the way in which matrix mechanics corresponded to classical mechanics was via the form of the equations of quantum mechanics, where the classical symbols for properties were replaced by their quantum matrix representation. In this paper I will compare these views of the correspondence principle. I will examine some different implications of each for the question of interpretation and will discuss how Bohr's and Heisenberg's views on the correspondence principle related to other aspects of their views about quantum mechanics. In particular, I will examine their disagreements about the uncertainty relations and the role of mathematical formalism in interpretation.

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