“Anschaulichkeit”, concept formation and the role of language in the immediate reception of quantum physics.

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Quantum physics is remarkable for the fact that even though everyone agrees with the empirical success of its abstract equations, consensus over it´s meaning is nowhere near as common. As we know, this has been so almost from the beginning of its history and recent historic studies have shown that even within the community that presented the “orthodox” interpretation, the Copenhagen school, the alignment of their aims did not necessarily mean uniformity in their opinions. The extensive dialog that happened during the 1920’s and 30’s is still a source of rich historical studies, among other things, because it forced physicists to engage in a very complex philosophical debate, one which is still unsolved. The philosophical problem arises from the fact that there seem to be no way to explain the success of the theory as part of a “classic” (empiricism, rationalism, idealism) philosophic system. New philosophy was need, and filling this gap was an integral part of the logic positivism movement that grew during that same period. In this presentation, I want to suggest that the philosophy made by physicists has as a common element an explicit need to reform Kant´s epistemology, from the very meaning of “a priori” and “anschaulichkeit”. Much in the same way in which we now understand the “European” community that brought about the Copernican shift as a group of natural philosophers that became convinced of the limitations of Aristotelian physics (despite the very different contexts where they all lived), I suggest that physicist philosophy of Quantum Physics in the German community should be understood in terms of their conviction that transcendental idealism was not enough to explain the new theory, and therefore, it had to be reformed. I will show that this is the case in the debate about “anschaulichkeit” between Schrödinger and Heisenberg, and in the original presentation of the complementarity principle by Bohr during the Como lecture (which is strongly connected to the previous debate, as we will see, by the need to redefine “a priori” and the role of concept formation) Additionally, I argue that almost none argued to abandon Kant’s philosophy, but rather to modify it and in most cases, relax the meaning of what a “necessary condition for the possibility of knowledge” is.

I.

When doing research for this paper, I came across an online forum that offered an English translation of Heisenberg’s 1927 paper , in which “anschaulichkeit Inhalt” was translated as “the actual content”. Almost immediately, a named user NikolajK posted: “As a German speaking person, I'd like to add that I find the translation "actual content" a little debatable. It sounds harsher than "anschauliche Inhalt", which could be translated to "the content which can actually be visualized (maybe opposed to that which is formal but has not clear correspondence to something real)"

Now, I’m not a German speaker, so I can’t fully asses the correctness of this complain, but what I can assure is that this apparently innocent problem with how anschaulichkeit should be translated to English only partially reflects the deeper problem which is that, even between competent German speaking subjects, the meaning of this term varies, as the debate between Heisenberg and Schrödinger shows. The difference of the meaning can be understood in terms of the different way in which they understood Kant’s “a priori”.

For Schrödinger, the context in which “anschaulichkeit” should be interpreted is classic

epistemology. In these case, the English possible translations as “visualizability” mixes with “intelligibility”. According to this reading, explaining a phenomena means being able to produce a clear “visualization” that then sheds light on the underlying causal connections between the empirical findings. Even further, “visualization” should be understood as a space-time description of the phenomena. For example, the atomic theory increases our understanding of thermodynamical properties, because we gain “anschaulich” by being able to form a clear spacious-temporal description that connects the kinematic energy of the atoms with its temperature. So this may be considered a good explanation even if it turn out that atoms have no independent existence. How does this reading relate to classic philosophical tradition? Well, they go back all the way to one of the first philosophers of modern (in the philosophical sense) natural science and supporters of the idea of the “method”: Rene Descartes.

When searching for the possible certainties that where clear of all doubt, Descartes suggests that there is an ontological division between the subject of knowledge and the matter of knowledge, between the self and the world, and that it is within the capabilities of the subject to distinguish between “clear and distinct ideas” from the rest of ideas. It was a capability of the mind (or, to put in historical term’s, of the spirit) to recognize certainty from uncertainty by assessing the “clearness” of the idea that the subject formed. The very notion that the propositions that we are compelled to believe as truthful without relying on evidence (such as 5+7=12) are a due to an ability or characteristic of the spirit served as a mayor argument for the rationalistic attitude of the early enlightenment, an was still a very seductive notion, even after Kant had treated it with the Copernican turn. But being educated within the German community, as he was, it is very likely that Schrödinger is actually using “anschaulichkeit” in the Kantian sense.

For Kant, the matters of science are the synthetic *a priori* propositions, which the transcendental subject forms by “categorizing” empirical data through the “conditions of possibility for knowledge” (i.e. space and time) and through “pure concepts of the understanding” (i.e. categories like causality, possibility or plurality). Therefore, even if the existence of oneself appears to be a clear and distinct idea, it is not a matter of science if there is no way to categorize it in terms of space, time, causality and so on. Because the synthetic *a priori* propositions require, for their mere possibility, such complex filters, they bring with them “anschaulichkeit”, and this is what science should aim for (according to Schrödinger).

So, when faced with Bohr’s rupture of phenomena into classic and quantum descriptions, or Heisenberg’s completely abstract treatment of the quantum relations, Schrödinger sets out to find an explanation that included his notion of “anschaulichkeit”, and he found it in his wave equation. So his initial interpretation is that the particle behavior displayed in certain quantum experiments was due to wave-packages formed by interference of extended entities that oscillated according to a wave equation. And, in the beginning, this spacio-temporal description helped gain support, because it was undeniable that it provided much more intuitive tools to deal with the quantum strangeness, and Schrödinger himself referred to it’s “anschaulichkeit” as an advantage over Heisenberg’s alternative. This, I believe, represented exactly the common enemy that united the Copenhagen school, and who’s engagement proved to be so fruitful in the next years. In particular, its interesting that Heisenberg’s uncertainty principle was found precisely discussing the “anschaulichkeit” of the two equations for QP.

II.

Now, because Heisenberg's uncertainty principle was presented as integral part of the Copenhagen interpretation, it's tempting to imagine that his and Bohr's epistemological views would be aligned, but, as I said, we now have good reasons to believe this was not the case. In particular, Heisenberg never fully accepted the other key component of such interpretation, namely, Bohr's "Complementary Principle". This principle is still under debate, because its details entail the whole of Bohr's philosophical outlook but he never gave a clear-cut definition for it, and therefore, any summary of it ends up coming short to really grasp it. Knowing this, I don't pretend to have The correct interpretation, but I want to contribute to the debate by suggesting that the way in which Bohr deals with the quantum weirdness is strongly connected to a classic theory of meaning that is remarkably similar to the esthetics of transcendental idealism.

According to Kant, the necessity of the synthetic *a priori* propositions came from the fact that any possibility of knowledge had to be categorized. That is, any possible concept to our understanding has to be laid out in terms of a very narrow set of categories, outside of which, we can't make sense of experience. In a way, our knowledge of the world is limited, constrained to such categories, and there fore, there are certain aspects of the world that can´t be scientifically apprehended (in particular, metaphysics. This was the sense in which Kant made a "Critic" to pure reason). When Bohr delivers his Como lecture, he is fundamentally interested in how to remove the apparent "irrationality" of QP, uses this term repeatedly in his presentation, and by doing so he is voicing everyone's concern. No matter how much positivism you through at the theories (by this time, the logic version of it was a very promising project) it was no secret that rules of the subatomic world where very weird in deed. Bohr is aware of it, and the defense of his choices is not naïve to these problems. On the contrary, Bohr assumes that there is a fundamental limitation to our possibility of knowing the world, certain conditions outside which nothing meaningful can be said. He gives arguments to try to convince his peers that there are good reasons to accept this limits of science as inescapable and tries to come up with the best possible philosophy that takes this premise seriously. His arguments in the Como lecture range, as they usually did, from discussing experimental settings, suggesting thought experiments and discussing epistemic terms, but the key notion (to me) lies in the idea that we cannot think in physics outside our macroscopic intuitions. In Bohr's presentation, concept formation is determined by our immediate sense experience, and we cannot think outside the abstractions we've come to hold as true because of the value they have to deal with the world at our scale. The terms of our language are classically conceived, and to our knowledge, they are inescapable. For Bohr, any "visualization" (in the sense of Schrödinger's "anschaulich") is made of combinations of our classic concepts, which alone are not enough to account for the phenomena of the micro scale (hence the generalized sense of weirdness). That's the bad news. The good news is that if one uses two completely classical pictures, which in our scale seem contradictory (like the wave and the particle), we are able to build a scheme where they work together in a complementary way to deliver a good explanation. So Bohr acknowledges the fact that QP sounds irrational, explains why there is not much to do about it in terms of the classic formation of our concepts, and suggest that the "Complementary Principle" may be our best attempt to treat QP rationally, in terms of two classic pictures. It is not clear to me how much of his "concept formation theory" is philosophically informed. Maybe he had some of Kant's ideas in mind; it could also be that he is talking in a psychological level, where our success in every day experience

depended on the apprehension of reality as consisting of certain aspects; or even in evolutionary terms, where classic concepts can help survival, but from me readings, it seems more likely that he is thinking in the way laboratory practice shapes the concepts of the scientists, where their intuitions about the underlying phenomena to a set of measurements is formed by their repeated and careful interaction with the macroscopic devices that relates them (so, if I put the mirror here, the gauge there moves, and if I press this button, that pressure drops…). He was convinced that physical knowledge was limited, but weather this limitation came from "the conditions of possibility for knowledge", psychological or physiological factors, I cannot say. In any case, "Bohr's principal concerns were of a kind which, since Kant, have been commonly described as transcendental […] a fundamental concern with the necessary condition fro the possibility of (experimental) knowledge"

III.

While Heisenberg had a similar stance on the idea that there are limits to scientific knowledge, his understanding of the reasons for the limit where sharply different. "The earliest incarnation of Quantum mechanics (matrix mechanics) rested on the philosophical assumption that the classical notions of space and time became invalid inside the atom"He too believed that the way in which we form concepts limits what can be conceivable, but contrary to Bohr's adverted Kantianism, he wasn't convinced that there was a fixed set of concept that were inescapable. In Heisenberg's view, the filter through which we form our concepts is language, but language changes through history and therefore so does concepts. The fact that we find it intuitive to think of frictionless experiments of elastic collisions is certainly linked to concept formation, but has less to do with some intrinsic way in which are concepts most be fixed, than with the fact that Mechanics brought with it a whole language that allowed us to speak of them in a clear and relatable way. After all, there was a time in which such ideas where not meaningful. To think in terms of waves, or particles, had not much to do with a structure of concepts, and more with the available mathematical language we had when dealing with such phenomena, and to Heisenberg, it was perfectly conceivable that the present weirdness was deemed irrelevant in the light of a future language. "The disagreement between Bohr and Heisenberg then, should not be construed, as some scholars have done, as a dispute between the epistemic standpoint of Heisenberg and the semantic standpoint of Bohr, but rather as between two different semantic conceptions"

To be fair, Heisenberg's mature philosophical stance was only fully formed in the 1930's, but the conclusions at which he arrived help us understand the kind of reading he made in the early years of his formulation of Quantum Physics. In particular, we can trace how his understanding of "anschaulichkeit" in the paper of 1927 is connected to his disagreement with Bohr and Schrödinger, and it's role in his latter revised notion of "a priori". In many senses, Heisenberg is following the same strategy that we see in Einstein's 1905 paper that presented special relativity: trying to redefine kinematic concepts in terms of experimental ways to measure them. Focusing on providing a theory that used only such "observable" quantities, he stated:

"We believe we have gained anschaulich understanding of a physical theory, if in all simple cases, we can grasp the experimental consequences qualitatively and see that the theory does not lead to any contradictions"

The interesting feature of this view, and one that would become and integral part of Heisenberg's` interpretation, is that the status of a physical theory can only be

determined holistically, since the only restriction imposed to the operational definitions is that the theory built upon them has no contradiction, and this can only be assessed if the theory is complete. This is why he insisted so much in the "completeness" of his formulation of Quantum Physics. And this means that the correct meaning of a theoretical term (such as position or momentum) can only be established once it's linked to observational quantities within a complete and consistent theory. So, although the operational definitions are clearly influenced by logical positivism (which was very influential during the period) Heisenberg's holist theory of meaning is actually a flagrant violation of basic precepts of that philosophy, every time that it is the context (the complete theory) which determines what should be considered "a priori" and what not, and therefore, no normative distinction can be established. In his view, it's the historically conditioned use of language that determines concept formation, and not the other way around. "A priori" concepts are necessary to build knowledge, but they are not unique, as Kant thought them. "Space, time and causality remain, for Heisenberg, the conditions for the possibility of experience, but unlike Kant [or Bohr], they do not have transcendental universality and necessity. Rather, such concepts have arisen through the historical development of human language, and turn out to have only limited range of applicability." He accepted that we need a concept of space that we take as primitive to be able to build a geometrical theory, but the value and pertinence of the concepts we take as primitives (the postulates) can only be measured once the whole system has been developed. (I frankly don't know, but wonder, how much influence did his time with David Hilbert had in this conclusion.) "To this extent, Heisenberg's redefinition of "anschulichkeit" can be viewed as part of the widespread reaction to Kantian philosophy in the first decades of the XX century".

We see that Heisenberg, as Schrödinger and Bohr, engages in the interpretation debate aware of the epistemological links between the new Quantum Theory and the German philosophical tradition, and promotes his version of anschaulichkeit using the Kantian contexts as a background. None of them completely rejected Kant's ideas: Schrödinger was very respectful and in that sense, traditional, or classic; Bohr saw the classic nature of "a priori" concept formation as the limitation that forced us to accept the complementarity principle, Heisenberg argued in favor of a historic reading of what "a priori" means. They where not Kant deniers, they where Kant's reformers.

Notice that I've presented here a small summary of the Kantian context surrounding the debate about "anschaulichkeit", language and concept formation, but I can assure that the same context is present in other important contemporary dialogs, ranging from the Einstein-Bohr debate, the problem of causality and uncertainty, the theory of measurement, but also logic positivism, philosophy of language and philosophy of mathematics. From this I conclude that the creative and bold attitude that we see in theoretical physics during the period was nurtured by the general awareness of the German community of the limitations of classic transcendental idealism. Camillieri, quoiting Chevalley said of Heisenberg: " By situating [his] though against the background of post-Kantian philosophy in the German speaking world, it becomes evident that many of the themes with which he was concerned in the 1920' and 1930's where "consistent with the mayor issues of philosophical though at the turn of the twentieth century"". I'm convinced the same can be said about most of the theoretical physicist of the time.

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