Karl Popper's engagement in quantum physics in the 1960s

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Abstract: The philosopher Karl R. Popper has been, since as early as 1934, one of the foremost critics of the Copenhagen interpretation of quantum mechanics, accusing it of subjectivism. In 1967, Popper published the paper "Quantum Mechanics without the Observer", which had a certain resonance among the physicists and gathered appreciations from many illustrious ones (e.g. L. De Broglie, D. Bohm, A. Landé, M. Bunge, H. Bondi, B. van der Waerden). It belongs to the same period one of Popper's most controversial publications in the highly quoted journal *Nature*, in which the author claimed to have found an error in a momentous paper, by G. Birkhoff and J. von Neumann, that initiated the research on Logic of Quantum Mechanics. Consequently, Popper entered an intense debate which divided the physics community. I present, for the first time, a reconstruction of this debate, also thanks to Popper's personal correspondence and unpublished documents. As a matter of fact, in the late 1960s, Popper essentially became part of the community of physicists concerned with foundation of quantum mechanics.

Keywords: Foundations of quantum mechanics, Karl Popper, logic of quantum mechanics, Copenhagen interpretation.

1. Introduction: Popper's early interest in Quantum Mechanics

It is by now common knowledge that Karl R. Popper (1902-1994) has been one of the greatest philosophers of twentieth century. His contributions to political philosophy, probability theory, and especially to philosophy of science have nowadays the most profound impact also on society in general. His name is inextricably entangled with the methodology of "falsificationism", which he proposed as early as 1934 in the most famous book *Logik der Forschung* (Popper 1934; English edition *The Logic of Scientific Discovery*, Popper 1959a).

However, historiography has paid little attention to another line of research ceaselessly pursued by Popper for about six decades: his active involvement in Quantum Physics. In fact, as early as in his already quoted book (Popper 1934), Popper put forward a courageous critique of the orthodox Copenhagen Interpretation of Quantum Mechanics (CIQM), accusing it of being anti-realistic and subjectivist. He even proposed a *Gedankenexperiment* similar to the EPR paradox (to be published the following year),

with the aim of proving the standard interpretation of Heisenberg's uncertainty principle false. Although the thought experiment was actually mistaken, this episode allowed Popper to have direct interactions with the major founding fathers of Quantum Mechanics (QM), the likes of Einstein, Bohr, Heisenberg, etc. (see Del Santo 2017; and Popper's autobiography: Popper 1976). However, Popper remained ashamed of his mistaken proposal, and this prevented him to put forward any new critiques of QM for several years.

Around 1948, thanks to his friend, the Austrian physicist Arthur March, Popper came back to fundamental problems of quantum physics with renewed enthusiasm. However, times had changed: World War II had reshaped the socio-economical balance of the whole world, and this was obviously reflected in the academic environment. With the Cold War paradigm enforcing, and following the lead of US, western science turned into a capitalistic enterprise, aimed at producing immediate practical applications, very often with military scopes (see e.g. Kaiser 2011, Baracca *et al.* 2017). Fundamental research – that had been at the core of the scientific revolutions of the pre-war period (QM, relativity) – was set aside, or in many cases openly opposed by funding agencies and academic institutions.

So, it is in this unfriendly context that Popper restarted addressing the many fundamental problems left open in QM. In 1948, he gave a talk on "Indeterminism in Quantum Physics and in Classical Physics", and he presented it again at the Harvard University and in Princeton in 1950 (attended also by Einstein and Bohr). The matter subject was then published in a paper (Popper 1951).

The 1950s became a period of prosperity for Popper's activities on quantum mechanics. Around 1953 he started developing the *propensity interpretation of probability*, an objective interpretation that treats probabilities as physically real entities (in the sense that they can be manipulated by changing the experimental apparatus) that guide physical objects. These probabilities (propensities) are such that they reproduce the actual collected statistics, but, contrarily to the *frequency interpretation* of von Mises (that Popper supported until that time), propensity interpretation can also explain single-case probabilities. Popper's propensity interpretation was firstly presented in 1957 in Bristol (Popper 1957) before an audience of physicists, who however did not give any consideration to Popper's proposal for at least a decade. In 1959 Popper published a second work (Popper 1959b), devoted to propensity interpretation too, but this was clearly aimed at philosophers of probability and logicians.

Moreover, during the first half of 1950s, Popper worked at the preparation of a *Postscipt to the Logic of Scientific Discovery*, an addition of his book (Popper 1934) that was about to be published in English translation. In the *Poscript* (eventually published as late as 1982 in three volumes: Popper 1982), Popper systematised his critique of the CIQM.

As a matter of fact, we have to stress that all of these activities met almost no interest in the physics community and remained largely confined in the circles devoted to philosophy of science proper, or at best philosophy of mathematics and logic (propensity interpretation of probability). In fact, up until the late 1960s, Popper had few direct contacts with physicists concerned with foundations of quantum mechanics (FQM) and

these were merely based on personal acquaintances and friendships. This is the case of Alfred Landé, David Bohm, Wolfgang Yourgrau, Mario Bunge and Hermann Bondi (the latter was actually an eminent cosmologist and he never worked on quantum physics). Besides the staunch support of these physicists, Popper was carrying out his battle against CIQM essentially alone. As William Bartley III ‐ Popper's former pupil who more than any other followed his work on quantum physics ‐ put it,

> one might have hoped for a classically heroic battle wherein the physicists gave the challenger no quarter ‐ and the challenger [Popper] required none. In fact, the physicists have for the most part simply ignored Popper (Bartley 1978).

2. Popper's contribution to Quantum Mechanics in the 1960s[1]

Popper's engagement in the FQM assumed a different status at the end of 1960s. It is indeed possible to claim that at that time, Popper became essentially active part of the community of physicists concerned with fundamental issues of quantum physics: he started having regular correspondence and discussions with eminent physicists, publishing in specialized physics journals (e.g. *Nature*, see Section 2.2) as well as giving contributions in conference aimed at an audience of physicists. Although almost neglected by historians, from the 1960s on, this actually became one of Popper's foremost research interests, and, although not free of mistakes, Popper's proposals surely had a resonance in certain circles of 'dissidents' who were concerned with FQM, and in particular with the reestablishment of realism in quantum mechanics (see Freire 2014). Besides the quite vast primary literature available, the present reconstruction is based on Popper's private correspondence and unpublished material, retrieved at the Popper's Archive of Klagenfurt (Austria) (Klagenfurt, Alpen-Adria-Universität, Popper's Archives, henceforth PA).

A turning point of Popper's consideration in the community of physicists is a talk that he gave at the "International Symposium on Foundations of Physics", held in Oberwolfach (Germany) in July 1966. In fact, thanks to the support of the physicist and philosopher of Science, M. Bunge, Popper's contribution to that conference was to become a quite influential paper, with the significant title *Quantum Mechanics without the Observer* (Popper 1967).

2.1. Popper's "Quantum Mechanics without the Observer"

Quantum Mechanics without the Observer, represents Popper's first comprehensive attempt to systematize his criticisms of the CIQM, and in general of subjectivist interpretations of QM. Therein, Popper tried to "exorcise the ghost called "consciousness" or the "observer" from QM" (Popper 1967). In doing so, he showed that most of the odd features of quantum mechanics, including the wave-particle duality, the so-called col-

[1] This paper is a preliminary communication and part of research project that aims at fully reconstructing Popper's engagement in quantum physics over more than 60 years of his career. A more detailed account has been recently published in (Del Santo 2019).

lapse of the wave function or even the fundamental epistemological limit imposed by Heisenberg's uncertainty principle are part of a long series of misunderstandings created by the doctrine of Copenhagen, resulting in the "great quantum muddle". Moreover, Popper expounded, for the first time in such a clear and extensive way, his own realistic and objective interpretation of quantum mechanics, in the form of 13 theses. One of the most significant and innovative point of this work, is that, for Popper, interpretations of probability are inescapably entangled with interpretations of quantum physics. As such, Popper's propensities (probabilities) are interpreted as physically real fields of probability that are "a property (a physical property, comparable to symmetry or asymmetry) of *the whole experimental arrangement*" (Popper 1967, eight thesis).

This paper, started collecting a certain appreciation by some of the influential physicists striving for a realistic interpretation of quantum mechanics. The first to answer was indeed David Bohm, one of the most distinguished theoretical physicists in the field of FQM, who probably more than anyone else contributed to give hope to a formal realistic interpretation of QM. In fact, Bohm had developed the first *hidden variables* model (i.e. based on non-observable real quantities), that can fully reproduce the prediction of QM (Bohm 1952). Although Bohm was in touch with Popper since at least late 1950s, their intellectual relationship had been mostly focussed on Bohm's philosophical inclinations, and in more than one case it was him who asked for Popper's opinion on philosophical papers. With *Quantum Mechanics without the Observer*, however, Bohm for the first time seemed to actually pay attention, and even appreciate, Popper's endeavour in QM. Indeed, he wrote to Popper on March 3rd 1967, remarking:

> I feel that what you have to say about propensities makes a genuine contribution to clarifying the issues that you discuss (PA 84/19).

This remark strengthens the hypothesis that physicists had thus far ignored Popper's propensity interpretation, even the ones who, like Bohm, were close to Popper and had participated in the symposium where propensities were firstly presented (see Section 1).

Also Alfred Landé, who referred himself as Popper's "most staunch adherent among the physicists" (letter from Landé to Popper on 11/03/1963, PA 318/18) replied to Popper's paper, stating that "people who once have received the Nobel Prize turn out to be […] unable to see through the 'great quantum muddle' of their own creation" (letter of Landé to Popper on 05/09/1967, PA 318/18).

The prominent cosmologist Hermann Bondi, also friend of Popper, not only wrote that he appreciated the latter's new paper, but that he had even used Popper's ideas in his lectures on QM, delivered at the King's College of London. He wrote to Popper on September 17th, 1967:

> The eye-opener for my treatment of this course was your remark two years ago that quantum theory gives statistical answers because one asks statistical questions. On the basis of this extremely penetrating remark I had myself come to the conclusion that the notion of the Observer was redundant (PA 278/9).

What is noteworthy is that the resonance of Popper's *Quantum Mechanics without the Observer* eventually came out of Popper's circle of acquaintanceship, too. Bartel Leendert van der Waerden, a former student of Emmy Noether in Göttingen, wrote to Popper a laudatory letter on October 19th, 1968:

> I fully agree with your 13 theses, and I feel it was very good you expounded them so clearly. I also agree with your propensity interpretation of probability. I feel my ideas are in perfect accordance with your theses. I discussed them with Heisenberg, von Weizsäcker and Bopp […], and we all agreed" (PA 96/27).

This was for Popper the long-awaited recognition of his struggles. He immediately replied:

> Your paper – and even more your letter – mean more to me than you can possibly imagine. It would take a long letter to give you an idea of my very lonely 35 years struggle. Although I had some encouragement, there was much more that was discouraging; and your letter is by far the most powerful encouragement I ever received (Letter from Popper to van der Waerden on 28/10/1968, PA 96/27).

Popper's paper even reached Louis de Broglie, one of the founding fathers of quantum physics. He wrote to Popper a short but appreciative message on March 4th, 1969:

> Yourgrau has sent me two of your articles on the interpretation of Quantum Mechanics. I noticed with great pleasure that your ideas are very close to mine[2] (PA 96/7).

Popper's *Quantum Mechanics without the Observer*, which also received some severe rebuttals (for instance from Jeffrey Bub and Paul Feyerabend), surely has a tremendous historiographical value, since it allowed Popper to actively enter the debate over the quantum physics together with professional physicists.

2.2. The critique of the Logic of Quantum Mechanics

Meanwhile, Popper's criticisms against CIQM were levelled on a different ground, too. In fact, Popper published in 1968 a paper in the very influential journal *Nature* (Popper 1968), claiming that a famous paper by Garrett Birkhoff and John von Neumann (1936), which inaugurated the so-called *logic of quantum mechanics* (LQM), was based on a mathematical mistake. The LQM is an axiomatic approach to physics that describes systems as "experimental propositions" (or "yes-no experiments") and tries to find general structure of the proposition in the same fashion of pure logic. In this framework, it is possible to show that classical physics conforms to a Boolean algebra. However, Birkhoff and von Neumann proposed that quantum mechanics does not have a Boolean structure, inasmuch the distributive law is not fulfilled, due to the fact that QM allows for incompatible observables (i.e. not commuting operators). This approach experienced a revival

[2] «Yourgrau m'a communiqué deux articles de vous sur l'interprétation de la Mécanique Quantique. J'ai constaté avec grand plaisir que vos idées se rapprochent beaucoup des miennes».

in the 1960s and was largely improved by the school of theoretical physicist Joseph M. Jauch at the University of Geneva. It is likely for this reason that Popper decided to rebut a paper more than 30 years old. He criticised the very proposal of a relaxation of the distributive law on formal ground, maintaining that QM conforms to a Boolean algebra as much as classical physics does. Although it is far beyond the scope of this paper to enter into the details of Popper's (in fact formal) arguments, it his historiographically noteworthy that nobody rebutted Popper's paper for several years (the first rebut is Scheibe 1974), despite the great importance of Birkhoff and von Neumann's work, Popper's reputation and the popularity of the journal *Nature*. This has indeed been referred to an actual "unsolved historical case" (Venezia 2003).

However, what emerges from a more accurate archival research is that (*i*) Popper's paper (1968) was in fact only a part of a larger enterprise against LQM, and that (*ii*) Popper immediately entered a heated debate with the main exponent of the school of the LQM (especially Jauch) and (*iii*) A. Ramsay and J. C. T. Pool wrote a rebuttal intended for publication in *Nature* which however never appeared in print.

In fact, there are evidences that Popper wrote at least other two more voluminous papers on the same subject and try to publish them in the *Proceedings of the Royal Society* thanks to the help of Bondi (PA 94/9) and in the journals *Il Nuovo Cimento* and the *International Journal of Theoretical Physics* (PA 96/2), respectively.

As for the reaction of the adherents to LQM, it is remarkable that as early as October 10th, 1968 (Popper's paper had appeared only in August) Ramsay and Pool sent to *Nature* some "Remarks on a Paper by Karl R. Popper" (PA 96/18). Therein they firstly put forward the critique that Popper had misinterpreted Birkhoff and von Neumann's proposal: a critique that has been partly confirmed in recent works (see Venezia 2003 and references therein). Popper too wrote a reply to his critics and sent it back to Nature for publication. However, "due to accidental but never fully clarified circumstances none of these papers, although obviously written for publication, has ever appeared in print" (Jammer, 1974, pp. 353).

This episode exacerbated the tensions between Popper and the initiator of the revival of LQM, J. M. Jauch. They have had, in fact, a long epistolary exchange for over a year, between February 1968 and February 1969. The failure of the publication of Ramsay and Pool's paper led indeed Jauch to accuse Popper of collusion:

> You have published in a widely read periodical criticisms of an important paper, which you have certainly misunderstood. I have tried to suggest to you to correct your mistakes yourself and that would have finished the matter. You realize of course that the entire scientific progress depends on the possibility of free exchange of scientific information and criticism. […] Did you not say yourself in the "Open Society and its Enemies" the spirit of science is criticism. If you believe that, I suggest that you send the enclosed copy of the manuscript by Ramsay and Pool to Nature with your personal request that it be published (Letter to Popper on February 24th, 1969. PA 96/18).

This triggered the reaction of Popper, who replied:

> You remind me in your letter of my conviction that "the spirit of science is criticism". I do not see what can give you the right to suppose that there is a need to remind me of this; or what your remark may mean unless you wish to accuse of dishonesty (letter from Popper to Jauch on February 28th, 1969. PA 96/18).

Although Popper solicited the publication, this diatribe remained confined on the pages of many letters exchanged by Popper not only with Jauch, but also with many eminent physicists and mathematicians, among whom D. Finkelstein, S. Kochen, A. Shimony.

3. Conclusion

We have shown that throughout the decade after 1948, Popper came back to the fundamental issue of QM, strengthening his critique of CIQM. The 1950s saw, indeed, a steady increase of Popper's activities concerning QM, ranging from the first drafting of his *Postscript* to his new propensity interpretation of probability. However, it was only after mid-1960s that these activities blossomed into an actual involvement of Popper in the community of physicists with controversial, yet significant, publications.

Acknowledgements

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