Franco Selleri and Karl Popper: fighting side by side for realism in physics

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Abstract: Franco Selleri (1936-2013) has been the initiator and foremost proposer of a revival, in the 1970s, of the research on foundations of quantum mechanics in Italy. He criticised the dogmatism of standard quantum physics and supported the idea of hidden variables to re-establish realism in physics. Moved by similar realistic motivations, the preeminent philosopher of science Karl R. Popper (1902-1994) had been a critic of the standard (Copenhagen) interpretation of quantum mechanics since as early as 1934. Popper and Selleri met at the beginning of the 1980s and established a flourishing intellectual relationship that represents an emblematic example of the possible interplay between physics and philosophy.

Keywords: Franco Selleri, Karl R. Popper, Foundations of Quantum Mechanics.

1. The general situation of the research on foundations of quantum mechanics in the post-war period

The present communication aims at paying homage to Selleri's legacy on foundation of quantum mechanics (FQM) with a focus on the long-lasting and close intellectual relationship that he established with Karl R. Popper in the 1980s. This essay is mainly based on two recently published works that reconstructed, respectively, Selleri's early effort to revive FQM (Baracca *et al.* 2017) and Popper's involvement in quantum physics in the 1980s (Del Santo 2017).

Although quantum mechanics (QM) was completely formalised already in the early 1930s, the interpretation of its theoretical entities has long been object of heated debate (and still is to date). The interpretation that became mainstream among the physicists was mainly elaborated by N. Bohr and W. Heisenberg and went down in history with the name of *Copenhagen interpretation of quantum mechanics* (CIQM). This interpretation requires the concept of the *observer* actively acting on a quantum system and, in this way, realising one of the possible outcomes of a quantum measurement. This viewpoint strongly challenged many of the fundamental assumptions of classical physics and in particular the concept of *objective reality* (i.e. the fact that physical variables possess predetermined values that are merely revealed and not influenced by measurements).

Popper was among the first scholars to argue against CIQM (together with some of the founding fathers of QM the likes of Einstein, Schrödinger, de Broglie) and to propose experiments aimed at violating that interpretation (see Del Santo's contribution to this volume and references therein).

Due to its pragmatic approach, CIQM acquired more and more adherents in the post-war period (whose productivist aim is encapsulated by the expression "shut up and calculate"), whereas the hope of completing the theories with underlying *hidden variables* that could have restored realism seemed lost (in fact von Neumann had allegedly proven this impossible; see Freire 2014).

Contrarily to von Neumann's forecast, in 1952, David Bohm developed an old idea of L. de Broglie, the pilot wave theory, formulating the first hidden variable model that reproduces all the predictions of QM.

The French physicist J.-P. Vigier, a pupil of de Broglie, became immediately interested in Bohm's approach and visited him for a period of collaboration which led to novel developments of Bohm's hidden variables theory. Vigier played a pivotal role in the popularization and promotion of the criticism of CIQM and for decades he has been in the front line for a realistic interpretation of QM, connecting and coordinating different groups of dissidents based in Europe (including Popper and Selleri).

But the real turning point for the FQM came in mid-1960s when John Bell put forward a theorem, in the form of inequalities that bear his name (Bell, 1964), capable of experimentally discriminate between quantum theory and local realism. However, the widespread hyper-pragmatic paradigm in the physics community in that period, prevented the theorem to receive any attention for many years, with the exception of a few groups of "dissidents" (see Freire 2014) who strove for finding room to foundational research on quantum theory. Among them were Karl Popper and Franco Selleri.

2. Selleri revives the FQM in Italy (1969-1970s)

At the beginning of 1960s, soon after his graduation, Franco Selleri gave important contributions to high energy physics, but as early as 1965 he became unsatisfied with modern physics and in particular with the interpretations of QM. In 1969 he published a first note (Selleri 1969) that was more the statement of a research program than an original contribution to the field, but that surely represented at that time a genuine shift of perspective in the Italian panorama. In fact, therein Selleri popularised the idea of a double ontology of particles and waves, adhering to the hidden variable program:

> No physical phenomenon is known which disagrees with the predictions of quantum mechanics (Q.M.). Nevertheless, several physicists found it very hard to accept this theory as basically correct. […] Even though the theories of hidden variables are not completely developed, an important shift of philosophical attitude can be noticed: particle and waves are now objectively existing entities (Selleri 1969).

In the same year, Selleri established contacts with L. de Broglie who – having recently breathed new life into his own idea of pilot wave, thanks to the effort of Bohm and of his student J.-P. Vigier – appreciated the work of the Italian physicist. Moreover, Selleri delivered, still in 1969 in Frascati (Italy), a series of lectures on *Quantum theory and Hidden Variables*. From then on, the critical realistic approach to QM became one of Selleri's main research topics and, making use of the recently formulated Bell's inequalities, he started proposing experiments to empirically discriminate between QM and (realistic) hidden variables theories.

Worth mentioning is that thanks to Selleri's endeavour and critical activities, a young and radical generation of Italian physicists started questioning standard QM, with the hope of opening a complete new physical framework that could have legitimised their critiques of the prevailing scientific attitude. Selleri, in fact, became member of the Steering Committee of the *Italian Physical Society* (SIF) and in that context he managed to organise, in 1970, one of the most influential meeting of the post-war period on the FQM: The International School of Varenna on FQM (see Baracca *et al.*).

Selleri remained for his whole life a leading figure in the Italian research on FQM (besides relativity and high energy physics) always upholding a genuine radical and critical approach to science, animated by strong ideological-political motivations. His work inspired a whole generation of physicists whose legacy left a long-lasting mark in the attitude towards science and its historical and social interpretation.

3. Popper and foundations of quantum physics

As already recalled, Popper levelled criticisms of QM already in the 1930s, when, in his most famous *Logik der Forschung* (Popper 1934) he put forward a though experiment allegedly discriminating between CIQM and a (statistical) realistic interpretation of quantum formalism. The experiment was however mistaken (see Del Santo 2017) and prevented Popper from contributing further to the debate over FQM for many years. In the 1950s, however, he came back to this topic with increasing enthusiasm. But it was only at the end of 1960s that Popper strengthened his criticism of CIQM with two influential papers (Popper 1967; 1968) that allowed him to establish new relationships with those outstanding physicists concerned with FQM and supporters of realism.

Redhead encapsulated Popper's endeavour with the words:

> Popper fought a lone battle against the Copenhagen interpretation at a time when anyone attempting to criticize orthodoxy was liable to be labelled at best an "outsider" or at worst a crank. But Popper's carefully argued criticisms won the support of a number of admiring and influential physicists (Redhead, 1985, p. 163).

Indeed, Popper was for many years in touch, besides many others, with Bohm and became more and more close to Vigier. It was in fact the latter who, from 1980 on, opened new room for Popper in the community of physicists and introduced him to Selleri.

4. Selleri and Popper (1980s)

4.1. Popper's EPR-like experiment

In 1980, Vigier convinced Popper to co-author a paper with him and A. Garuccio (a pupil of Selleri in Bari) about a possible test to experimentally detect de Broglie's pilot waves (Garuccio *et al.*). Thanks to the discussions related to this collaboration, Popper devised a new thought experiment that – similarly to the original EPR proposal (Einstein *et al.* 1935) – made use of the phenomenon of *quantum entanglement* to show an inconsistency of orthodox interpretation of QM. In particular, Popper's idea was that of experimentally violate the standard interpretation of Heisenberg's uncertainty principle (i.e. a fundamental epistemological limit) and the whole CIQM along with it. With reference to Fig. 1, a source (*s*) generates a pair of particles entangled in position and momentum (like the original EPR). With this constraint the particles travel coaxially in opposite directions experiencing a complete anticorrelation (conservation of momentum). In position *A* and *B* are located two narrow slits (but not narrow enough to consider this a projective measurement but only a better localisation of the wave function). Due to the uncertainty principle, a more precise knowledge of the position of the particles (Δy) leads to a proportional uncertainty in the momentum in the corresponding direction (Δp_y). Therefore, the presence of the slits broadens the angle of detection of the particles (the semi-circular arrangements in figure are batteries of detectors).

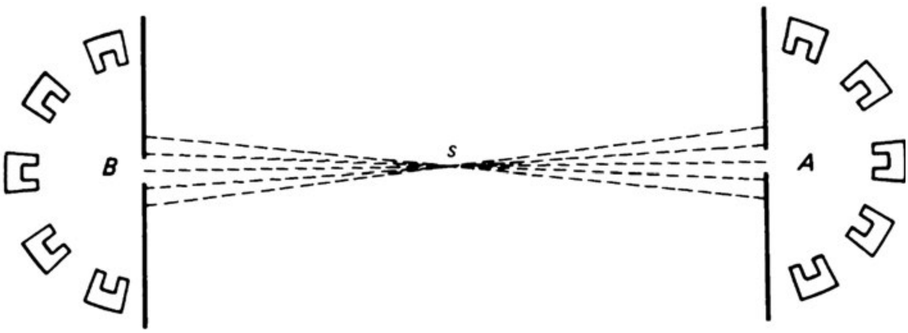

Fig. 1. Proposed setting of the source, slits and detectors in Popper's EPR-like experiment. (Reproduced from Popper 1982, p. 28, with permission of University of Klagenfurt/Karl Popper Library. All rights reserved).

Popper maintains that due to the entanglement between the momenta of the two particles, if one of the two slits is removed, the Copenhagen interpretation would predict that the other one will still undergo a broadening of the detection angle. Whereas, in his opinion, namely in a realistic interpretation, the particle in the path without a slit will travel straight without experiencing any deviation.

This experiment was firstly devised in 1980 (one of the present authors has recently retrieved the original letter and notes wherein the experiment was firstly conceived. See Del Santo 2017) and published in 1982 in Popper's book on quantum physics (Popper 1982). However, this book had probably little diffusion among the physicists and Popper's proposal had almost no circulation in that community. It was only when Vigier introduced it to Selleri that the consideration of Popper's experiment took a different course.

4.2. The Bari workshop of 1983

Selleri – who, as already recalled, had in his program the experimental violation of CIQM – surely was enthusiastic when Vigier presented him with Popper's experiment. He remembered in an interview:

> a conference was organized at the time to attract Karl Popper whom I understood then to be a very important philosopher for us, because Karl was very critical of the Copenhagen approach (Freire, 2003).

In fact, Popper and Selleri met for the first time at this conference held in Bari in 1983 and entitled *Open Questions on Quantum Physics*. This meeting was to have a great importance for Popper's role in the community of physicists inasmuch as several theoretical and experimental physicists were invited by Selleri with the precise aim of convincing them to realise the experiment. This was very important to Popper, who would state: "I plead here only that my experiment should be conducted by somebody" (Del Santo 2017).

Besides, this was the beginning of a sincere friendship between Popper and Selleri who had a remarkable mutual influence. Just after the conference, Popper wrote to Selleri (May 1983):

> It was a wonderful conference, probably the best I ever attended [...] for me the best was meeting you and became your friend […] As to my experiment [...] I am 81 and therefore rather anxious to see it realized (Del Santo 2017).

And Selleri replied (letter on 01/06/1983):

> you left behind not only feelings of intellectual admiration but of friendship as well (Del Santo 2017).

Selleri's admiration of the great philosopher and the full acknowledgement of the latter's work on FQM continued increasing in the following years. He wrote to Popper:

> Only after meeting you I really understood why the cultural spaces for our activities are so much broader than they were in the fifties (or in the thirties). It is your merit, in a considerable way. The champion of scientific rationality, as you are rightly considered, has severely criticized the standard formulation of quantum theory and found it affected ... of subjectivism" (Selleri to Popper 18/11/1984; Del Santo 2017).

Also long after, almost a decade after Popper's death, Selleri remembered him as

> The best philosopher of the 20th century, the best philosopher of science, by far, without comparison. […] every time he was critical he was right" (Freire 2003).

4.3. The fate of Popper's experiment

Selleri tried first to convince the Italian physicist De Martini, who had participated in the conference in Bari, to perform Popper's experiment and he even visited his laboratory in Rome. However, Selleri was disappointed by De Martini's way of doing physics and the project vanished.

At the same time, Selleri started working on the theoretical proposal of the experiment and found that a source producing collinear photons had fundamental problems.[1] Moreover, Selleri presented Popper's experiment in a conference in Athens in 1984, defending the possibility in principle of realising a suitable source of collinear photons against the position of the majority of physicists. However, Selleri published a paper, together with the Canadian physicist D. Bedford, demonstrating that Popper experiment "is impossible in principle [...] in all those cases in which the emitting source disappears in creating the 'collinear' pair" (Del Santo). This was Selleri's last word on the experiment proposed by Popper.

Thanks to the effort of Selleri and especially to the Bari conference, however, many other physicists got to know Popper's experiment throughout the 1980s and several of them published critical papers on Popper's proposal (H. Krips, A. Sudbery, G. C. Ghirardi, M. Collett and R. Laudon; see Del Santo 2017). Interestingly, their critiques were almost solely directed, like the one of Selleri, towards the impossibility of realising a suitable source.

It was only in the 1999, five years after Popper had passed away, that Y. Shih and Y.-H. Kim finally carried out the experiment, using the new technique of Spontaneous Parametric Down Conversion. They must have been stupefied when they found that their result confirmed Popper's theoretical predictions, i.e. a violation of the uncertainty principle! The authors however concluded that: "Our experimental result is emphatically NOT a violation of the uncertainty principle which governs the behaviour of an individual quantum" (Kim and Shih 1999).[2] It is historically relevant that none of the physicists working on Popper's experiment for more than a decade had questioned the cruciality of Popper's experiment, but only after the violation was found there was a race to disprove Popper.

Today the vast majority of the physicists agree on the fact that Heisenberg's uncertainty principle is preserved, inasmuch as Popper's experiment is not an *experimentum crucis*: Popper's interpretation and CIQM give the same predictions.

5. Conclusions

Although today few physicists would subscribe Popper's and Selleri's ideas on quantum theory, their work deserve to be recalled as an example of genuine collaboration

[1] We must stress that at that time the only source of entanglement photons were atomic cascades.

[2] The reaction of the physics community to the possibility of a violation of the Uncertainty principle was regrettable. Kim and Shih saw their manuscript refused by the most influential journals on the basis of the prejudice that this was unacceptable. See Del Santo (2017) for a detailed reconstruction.

between physics and philosophy in an inextricable endeavour against instrumentalism. Their bold and remarkable initiative have contributed to come out of an era of undisputed scientific productivistic pragmatism and laid the basis for the modern interest towards FQM.

Acknowledgements

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