Book Review


For more than twenty-five years Wim de Muynck has been publishing significant, and sometimes provocative articles on the foundations of quantum mechanics. The thick volume that has now appeared reflects this work, and combines it into one coherent whole. There are two main themes in the book: the formalism of "generalized quantum mechanics" and its applications, and a specific empiricist interpretation of quantum theory that according to de Muynck accommodates the technical results in the most natural way.

The formalism that is explained, developed and systematically used by de Muynck revolves around the concept of positive operator-valued measures (POVMs). These generalize the projection-valued measures (PVMs) occurring in the usual textbook treatments of quantum mechanics. In the PVM formalism each physical quantity is associated with a definite Hermitian operator, which via its spectral resolution determines a set of projection operators (each one corresponding to a different possible outcome in a measurement of the quantity in question). The POVM formalism replaces these projectors by a set of positive operators $M_n$ that add up to 1; the probability of finding possible measurement outcome $n$ becomes $\text{Tr} M_n \rho$, with $\rho$ the density operator. It is the set of positive operators that now characterizes the physical quantity, and there is no longer one representative "observable." This way of dealing with physical quantities is the most general one possible, as long as one stays within the Hilbert space formalism.

Wim de Muynck demonstrates that most experiments that are actually performed in the laboratory are more naturally described by the POVM formalism than by projectors (it is true that by virtue of Naimark's theorem a PVM treatment is always possible in principle, but such a treatment often involves the introduction of additional degrees of freedom.
that make the discussion needlessly complicated). The superiority of the POVMs is particularly clear in the case of non-ideal measurements. De Muynck develops the POVM approach systematically here: he formulates a general theory of non-ideal measurements, which leads to a partial ordering of non-ideal measurements, quantitative measures of non-ideality, a scheme for the joint non-ideal measurements of incompatible observables, and measures of complementarity. He also applies the formalism to a substantial number of concrete examples, like joint non-ideal measurements of position and momentum, neutron interferometry, Stern–Gerlach experiments, several types of quantum optical experiments (e.g., homodyne detection), and a variety of interference experiments with atomic beams.

The POVM formalism thus turns out to be an extremely useful tool in the discussion of measurements. Now, it is well known that on the level of measurement results there is no direct non-locality (EPR-like correlations do not give rise to the possibility of superluminal signaling). In other words, the POVM formalism provides us with a consistent and local scheme of dealing with measurement outcomes. So, if we consider the POVM scheme to be merely about observational data, we apparently possess a consistent and local theory of quantum phenomena. This is one of the themes in the more philosophical parts of the book: de Muynck there argues for a strict empiricist approach to quantum mechanics that circumvents many of the notorious interpretational problems.

Wim de Muynck’s empiricism shares a sceptical outlook with the several brands of empiricism on the philosophy of science market, for instance van Fraassen’s constructive empiricism; but there are also marked differences. Like van Fraassen, de Muynck thinks that a scientific theory can be good without being true: the only thing that really counts in science is whether our theories are in accordance with experience—whether they are empirically adequate. Van Fraassen combines this with an agnostic attitude concerning the unobservable entities that occur in our scientific theories. They might exist, but we cannot have reliable knowledge about their existence. That is because in general there will be many theories that equally save the phenomena, some of them with completely different ontologies, and all scientifically acceptable since they lead to the same observable predictions (although there may be pragmatic grounds making one of them more attractive than the others, e.g., the use of familiar mathematical techniques). Because empirical adequacy is the ultimate scientific goal, it is not really necessary that scientific theories supply explanations, by linking regularities in experimental results to regularities in the behavior of entities on a deeper, unobservable, level. De Muynck joins van Fraassen in this rejection of the realist demand that good theories should provide explanations. But, unlike van Fraassen, de Muynck is not skeptical about