Need for Pluralism in Philosophy of Quantum Mechanics

(submitted 2025 &HPS10 extended abstract)

Steven Meyer
smeyer@tdl.com
August 26, 2024

Abstract: This paper argues that quantum physical (QM) explanations need to be revisited using the principles of pluralistic philosophy of science. Part of pluralism is study of the historical development of scientific theories (research programmes). There has always been a view that QM explanations can be improved. The paper lists a number of of perceived problems with QM. Although the standard quantum model successfully predicts behavior in particle accelerators and chemical spectrums, there have been much criticism of QM explanations. A number of proposed alternatives are discussed. This paper argues that pluralism is needed because accepted scientific explanations lack inevitability. Many of the criticisms of current QM question application of formal mathematics to physical understanding. The paper argues that current QM needs to study microphysics that is not high energy physics and is not physical chemistry. A number of promising areas from historical study are discussed. The paper concludes with a discussion of the assumptions of quantum computer construction.

There have always been a number of unsatisfying methodological problems with the natural philosophy explanations of quantum phenomena (Myrvold[2022] for example). Examples are: instantaneous collapse of the wave function, different measurement results from observation, seeming validity of Niels Bohr's complementarity principle that states the wave and particle models are both required but are mutually exclusive. Also, entanglement and action at a distance among others.

It is not clear that mathematical explanations apply everywhere both geometrically and among theories. Although, the standard quantum model is successful in calculating experimental results especially at high energies in particle accelerator measurements and spectrum measurements. Another possibility is David Bohm's qualitative infinity of nature theory (Bohm[1957]) that argues each different aspect of quantum physics needs a different qualitative explanation. Mathematics may not provide suitable explanations in some aspects of quantum theory.

This paper argues that both what Hasok Chang calls theoretic pluralism (Change[2013]) and Imre Lakatos (Lakatos[1976]) and his student Donald Gillies (Gillies[2023]) would call research programme competition involving historical and methodological studies are needed. Possibly it would be better to call this quasi-empirical mathematical physics. Chang writes "More specifically, philosophical critique and questioning can often show that currently accepted knowledge lacks inevitability (p. 9)."

Motivation for this paper comes from an attempt to defend Hans Reichenbach's idea that three valued logic is needed to explain quantum phenomena (Reichenbach[1944]). In my view, Reichenbach makes this questionable assumption (see also Feyerabend[1981c]).

The rules of logic cannot be affected by physical experience. If we express this idea in a less pretentious form, it means: if a contradiction arises in physical relations, we shall never consider it as due to formal logic, but as originating from wrong physical interpretations (p. 208).

1. Current Physics

Physics correctly believes that the standard model explains results of particle collisions in high energy accelerators (Wikipedia[2024] and Wikipedia[2024b]). However, there is also belief that nothing will be found if higher energy particle accelerators are constructed. As Flavio Del Santo writes (Del Santo[2017], p 4). The era of "shut up and calculate" needs to be over. I am arguing there is a need for study of low energy quantum microphysics.

2. Physicist skepticism toward formal mathematics.

There has been skepticism by physicists of mathematics outside of differential geometry going back at least to Albert Einstein in 1921. The paper analyzes historical viewpoints of the founders of quantum physics in detail. Einstein wrote:

This view of axioms, advocated by modern axiomatics, purges mathematics of all extraneous elements. ... such an expurgated exposition of mathematics makes it also evident that mathematics as such cannot predicate anything about objects of our intuition or real objects (Einstein[1921]).

Felix Bloch in his AHQP interview with Thomas Kuhn states: "My impression that group theory is something tremendously important." Later on, I did think so much of it any more. (Bloch[19??] p. 34 on 1929-1931 research). At the 1938 conference on new theories in physics, Niels Bohr convinced John von Neumann to agree that his quantum logic was questionable (IntCoop[1934] end discussion section). In the early 1950s von Neumann rejected the mathematical concept of information as having physical validity (Kohler[2001]).

Mathew Sands (Sands[1987]) wrote on teaching of physics at Cal tech in 1960.

Smyth did a classic book on electricity and magnetism which was all the ultimate in boundary value problems and exotic functions ... And I objected because I claimed it wasn't physics. It was high powered formal mathematics.

3. Promising areas for historical study

3.1 Bohr complimentary

Although the standard model of particle physics includes quantum states, particle accelerators are designed using Newton plus special relativity macro physics (see for example Sands[1970]).

3.2 EPR thought experiment

I think Einstein's skepticism toward current theories of QM should be taken more seriously. The multiple responses to the EPR experiment are in need of new historical studies. Starting with the original paper Einstein[1935], Bohr responded in Bohr[1935], Schrodinger responded in Schrodinger[1935]. There were many later responses. Among them: David Bohm's qualitative infinity and pilot waves (Bohm[1957]), John Bell's mathematical analysis (Bell[1964]). Karl Popper's Popper[1968| and Del Santos[2017]. Also Paul Feyerabend[1981, 1981a, 1918b]. Arthur Fine's criticism of Bohr's response to the EPR paper (Fine[1996]). Also the less sophisticated Hippies at Lawrence laboratory (Kaiser[2011])

3.3 Possible existence of quantum computers

I claim arguments for the existence of quantum computers incorrectly make assumptions from formal mathematics. In particular quantum algorithms assume validity of Turing machines (TM) yet von Neumann rejected the TM model for the MRAM model that is close to the hand calculating machines of the time (Meyer[2024]). It is possible Feynman's original lecture on computation were criticism of formal mathematics in physics.

3.4 Polya/Lakatos quasi-empirical mathematics

Incorrect assumptions in mathematics not specially about mathematical physics is the topic of sections 3 and 4 of Donald Gillies philosophy of mathematics book (Gillies[2023]).

4. References

Bell[1964] Bell, J. On the EinsteinâPoldolskyâRosen paradox. *Physics 1, 3(1964)*, 195-200. LI "Bohm[1957] Bohm, D. *Causality and Chance in Modern Physics.* Van Nostrand, 1957.

Bohr[1935] Bohr, N. Can quantum-mechanical description of physical reality be considered complete?, *Physical Review, 48: 695−702,* 1935.

Chang[2013] Chang, H. *HIstory and Philosophy of Science in the Service of Scientific Pluralism.* Funacao Calouste Gulbenkian, 2013. URL Aug. 2024: https://www.hps.cam.ac.uk/files/chang-scientific-pluralism.pdf

Del Santo[2017] Del Santo, F. Genesis of Karl Popper's EPR-Like Experiment and its Resonance amongst the Physics Community in the 1980s. *Studies in History and Philosophy of Science Part B Modern Physics,* January 2017.

Einstein[1921] Einstein, A. Geometry and Experience. *Lecture before Prussian Academy of Sciences.* Berlin, January 27, 1921, Nov. 2023 URL: www.relativitycalculator.com/pdfs/einstein_geometry_and_experience_1921.pdf

Einstein[1935] Einstein, A., Podolsky, B. and Rosen, N. Can quantum-mechanical description of physical reality be considered complete?, *Physical Review, 47: 777â780,* 1935.

Feyerabend[1956] Feyerabend, P. Notes on the Neumann-Proof. unpublished, Karl Popper Archive, London School of Economics, Box 294, File 18, 1956.

Feyerabend[1959] Feyerabend, P. Superstates in the Quantum Theory. unpublished, Karl Popper Archive London School of Economics, Box 423 file 6, [1959-1960?].

Feyerabend[1981] Feyerabend, P. On the quantum theory of measurement. in *Philosophical papers. Vol. 1.* 207-235, Cambridge, 1981.

Feyerabend[1981a] Feyerabend, P. Niels Bohr's world view. in *Philosophical papers. Vol. 1.* 247-297, Cambridge, 1981

Feyerabend[1981b] Feyerabend, P. Hidden variables and the argument of Einstein, Podolsky and Rosen. in *Philosophical papers. Vol. 1.* 298-297, Cambridge, 1981.

Feyerabend[1981c] Feyerabend, P. Reichenbach's interpretation of quantum mechanics. in *Philosophical papers. Vol. 1.* 236-245, Cambridge, 1981.

Feyerabend[2016] Feyerabend, P. *Physics and Philosophy: Volume 4: Philosophical Papers.*, Gattei, S. and Agassi, J. (eds.) Cambridge, 2016.

Feynman[1996] Feynman, R. (Hey, A. and Allen, R. eds.) *Feynman Lectures on Computation.* Perseus, 1996.

Fine[1996] Fine, A *The Shaky Game: Einstein Realism and the Quantum Theory.* (new edition), Chicago, 1996.

Gillies[2023]' Gillies, D. *Lakatos and the Historical Approach to Philosophy of Mathematics.* Cambridge, 2023.

IntCoop[1938] International Institute of Intellectual Co-operation, *New Theories in*

	Physics, Warsaw, 1938.
Kaiser[2011]	Kaiser, D. *How the Hippies Saved Physics: Science, Counterculture, and the Quantum revival.* Norton, 2011.
Kohler[2001]	Kohler, E. Why von Neumann Rejected Carnap's Dualism of Information Concepts. In Redei, M. and Stoltzner, M. (eds.) *John von Neumann and the Foundations of Quantum Physics.* Vienna Circle Institute Yearbook 8, Kluwer, 97-134, 2001.
Lakatos[1976]	Lakatos, I. *Proofs and Refutations* (Cambridge 1976).
Myrvold[2022]	Myrvold, W. Philosophical Issues in Quantum Theory. *The Stanford Encyclopedia of Philosophy,* Mar 23, 2022. URL Aug. 2024: https://plato.stanford.edu/entries/qt-issues/
Popper[1968]	Popper, K. Birkoff and Von Neumann's Interpretation of Quantum Mechanics. *Nature 219, 1968,* 682-685.
Putnam[1957]	Putnam, H. Three-valued logic. *Philosophical Studies 8(5):73-80,* 1957.
Reichenbach[1944]	Reichenbach, H. *Philosophic Foundations of Quantum Mechanics.* Dover, 1944.
Sands[1970]	Sands, M. *The Physics of Electron Storage Rings.* SLAC technical report SLAC-121, 1970. URL Aug. 2024: https://www.slac.stanford.edu/pubs/slacreports/reports02/slac-r-121.pdf
Sands[1987]	Sand, M. Interview of Matthew Sands by Finn Aaserud on 1987 May 4 and 5, Niels Bohr Library & Archives, American Institute of Physics, College Park, MD USA. URL Aug. 2024: www.aip.org/history-programs/niels-bohr-library/oral-histories/5052
Schrodinger[1935]	Schrodinger, E. The Present State of Quantum Mechanics. Dublin Institute translation, *Die Naturwisenshaftern 1935, vol 23, Issue 48,* 1935. LI "Wikipedia[2024]" Wikipedia. Standard Model of Particle Physics. URL Aug. 2024: https://en.wikipedia.org/wiki/Standard_Model LI "Wikipedia[2024b]" Wikipedia. Mathematical formulation of the Standard Model. URL Aug. 2024: https://en.wikipedia.org/wiki/Mathematical_formulation_of_the_Standard_Model