A philosopher looks at quantum mechanics (twice)

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146 Philosophy of Physics: Quantum Mechanics
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Hilary Putnam (*1926)

- phil of mind: hypothesis of multiple realizability, concept of functionalism
- phil of language: causal thy of reference, semantic externalism
- phil of mathematics: Quine-Putnam indispensability thesis
- phil of physics: disproof of openness of future based on special relativity
- contributions to metaphysics, mathematics, computer science
- epistemology: brain-in-vat argument against skeptic ("Brains in a vat", 1981)

The basic premise

Hilary Putnam (1965), “A philosopher looks at quantum mechanics”, in his *Mathematics, Matter and Method, Philosophical Papers Volume 1*, second edition, Cambridge University Press, 1979, pp. 130-158.

Hilary Putnam (2005), “A philosopher looks at quantum mechanics (again)”, *British Journal for the Philosophy of Science* **56**: 615-634.

Assumption (Scientific realism)

“According to [operationalism] statements about [certain magnitudes, such as distance, charge, mass,] are mere shorthand for statements about the results of measuring operations... I shall here assume that this philosophy of physics is false... According to me, the correct view is that when the physicist talks about electrical charge, he is talking quite simply about a certain magnitude that we can distinguish from others partly by its ‘formal’ properties..., partly by the structure of the system of laws this magnitude obeys..., and partly by its effects. *We know that [a charge meter] measures electrical charge, not because we have adopted a ‘convention’, or a ‘definition of electrical charge in terms of meter readings’, but because we have accepted a body of theory that includes a description of the meter itself in the langauge of the scientific theory. And it follows from the theory [...] that the meter measures charge...” (130f)*

An important consequence and the basic plot

- If his rejection of operationalism is right, Putnam infers, “then the term ‘measurement’ plays no fundamental role in physical theory as such”, i.e. “ ‘measurement’ can never be an undefined term in a satisfactory physical theory...” (132)
- Motivation (and goal) for paper(s): Can we understand or interpret QM in a way that is compatible with scientific realism, and if so, how?
- For the purpose of answering this question, Putnam then goes through various interpretations:
  1. First paper (1965): (a) de Broglie’s pilot wave interpretation, (b) “original” Born interpretation, (c) hidden variable interpretations, (d) Copenhagen interpretation
  2. Second paper (2005): (d) von Neumann/Copenhagen interpretation, (e) GRW, (f) many-worlds interpretation, (g) Bohmian mechanics

(a) de Broglie's pilot wave interpretation

- main idea: waves not mere representations, but physical entities

Difficulties:

- QM-waves, unlike real waves, have complex amplitudes, Hilbert space is not physical space, but mathematical abstraction
- "reduction of the wave packet" (aka collapse): nonlinear (Putnam says discontinuous, but this need not be so) change in physical wave upon measurement from being very spread out to highly localized wave packet is strange for physical wave

Putnam says: no to (a)

(b) "original" Born interpretation

- elementary particles are classical insofar as they are point masses w/ determinate position and velocities, but they don't obey classical laws
- wave fct doesn't represent state of system, but our incomplete knowledge of it
- can deal with difficulties of (a): no problem of wave being mathematical since it only represents our knowledge, and thus also no issue w/ collapse

Difficulties:

- Interference in two-slit experiments shows up physically as pattern on screen, so that quantum system must physically have wavy property
  - $\Rightarrow$ collapse requires that we think of waves not as physical, but interference patterns make no sense unless waves are physical
- Superposition

Superposition and the Principle of No Disturbance

If for a system $\hat{A}|a\rangle = \alpha|a\rangle$, $\hat{B}|b\rangle = \beta|b\rangle$, and $\hat{C}|c\rangle = \gamma|c\rangle$ such that $|c\rangle = \lambda_1|a\rangle + \lambda_2|b\rangle$ (with $[\hat{A}, \hat{B}] \neq 0$), then measuring a number of systems prepared to be in state $|c\rangle$ might result in:

(1) measurements of observable $\mathcal{A}$ yield α in 60% of the cases

(2) measurements of observable $\mathcal{B}$ yield β in 60% of the cases

(Q: how can this be if $\lambda_1^2 + \lambda_2^2 = 1$?)

- One cannot measure both (1) and (2) on the same systems, since measurement of $\mathcal{A}$ disturb the systems such that statement (2) cannot be checked (and vice versa).
- The following principle tacitly assumed by the Born interpretation is the culprit:

Principle (Principle of No Disturbance (ND))

"The measurement does not disturb the observable measured—i.e. the observable has almost the same value an instant before the measurement as it does at the moment the measurement is taken." (138)

- (ND) is incompatible w/ QM
- Before any measurement is made on the systems prepared to be in $|c\rangle$, (1) and (2) cannot both be true.
- But they would be according to (ND).

$\Rightarrow$ reject (ND) and thus Born's original interpretation

Putnam says: no to (b)

(c) Hidden variable interpretations

- You know what these are.
- Putnam's main (somewhat misguided) criticism in 1965: requires "quantum potential", i.e. some unknown force, for which there is no evidence, in order to account for the disturbance by the measurement (i.e. the violation of (ND))
- for Bohm: (ND) is valid only for position measurements
- Putnam thinks this is a mistake and argues against the validity of (ND) for any measurement.
- But his argument doesn't ultimately succeed, as he acknowledges in 2005.

Putnam says: no to (c)

Three conditions of adequacy

1. “The principle ND should not be assumed even for position measurement.
2. “The symmetry of quantum mechanics, represented by the fact that one ‘representation’ has no more and no less physical significance than any other, should not be broken. In particular, we should not treat the waves employed in one representation (position representation in the case of the hidden variable theorists) as descriptions of physically real waves in ordinary space.
3. “The phenomena of superposition of states... must be explained in a unitary way.” (145f)

(d) Copenhagen interpretation (CI)

- You know what this is. Reminder: particles don't generally have determinate properties, but only propensities to be unveiled by suitable experiments.

$\Rightarrow$ Born's rule slightly modified: squared amplitude of wave measures not probability that particle is in a certain place, but probability that it will be found in a certain place when a position measurement is made

- CI: Born's rule *plus* assumption of completeness of wave representation (*plus* collapse)
- no problem rejecting (ND): $\mathcal{A}$-measurements and $\mathcal{B}$-measurements cannot be made simultaneously ("complementarity")

How does the CI fare with the three conditions of adequacy? The first two are satisfied, the third is doubtful since superposition states are not explained, but posited as primitives.

Serious difficulties for CI

- Main difficulty: reliance on ‘measurement’ as primitive term $\Rightarrow$ violation of basic assumption of scientific realism
- various ways to spell it out are unsuccessful, bc they typically leave other terms primitive (such as ‘macro-observable’)
- This leads to the MP in the form of Schrödinger’s cat, and the attendant difficulty of making sense of the dual requirements of separating the world into the measured and the measuring and of demand of universal applicability of QM
- According to CI, micro-observable don’t exist unless measured (in Putnam’s words), but macro-observables take sharp values at all times ($\Rightarrow$ measurement is an interaction bw micro- and macro-observables).

$\Rightarrow$ macro-observables have special status insofar as they retain sharp values (and this is an underived assumption of the thy)

"The question we face is whether from such a quantum-mechanical characterization of a macro-observable together with the laws of quantum mechanics it is possible to deduce that macro-observables always retain sharp values whether a measurement interaction involving them is going on or not. If we can do this, then the appearance of paradox and the ad hoc character of the CI will disappear. In spite of a number of very ingenious attempts, it does not appear that this can be done." (150f, this last claim is essentially bc of Schrödinger's cat.)

Putnam says: no to (d)

In conclusion (1965)

"In conclusion, then, no satisfactory interpretation of quantum mechanics exists today." (157)

Addendum (2005)

- von Neumann's version of CI is rejected for similar reasons
- argument against HV is retracted, new interpretations (GRW, many worlds) are being considered
- focus shifts a bit from analysing interpretations (and rejecting them) to classifying them
- But before we do that, a new condition of adequacy: Einstein's bed

The problem of Einstein's bed

When Putnam joined the Princeton faculty in 1953, his PhD supervisor Hans Reichenbach organized for him to meet with Einstein. So they met and talked about QM, and what Einstein said on this occasion was something along the lines of the following:

> *" 'Look, I don't believe that when I am not in my bedroom my bed spreads out all over the room, and whenever I open the door and come in it jumps into the corner.' " (624)*

- ⇒ Einstein was critical of von Neumann's collapse postulate
- ⇒ Putnam: determinateness of measurement outcomes should naturally fall out of thy, not by simply adding some ad hoc principle (such as collapse)

Table: Kinds of interpretations of QM (Reproduced from Table 2 in Putnam 2005).

Collapse	*No collapse*
Produced by something external to the system and not subject to superposition (e.g. von Neumann)	No hidden variables (Many Worlds)
versus	*versus*
Spontaneous (e.g. GRW)	Hidden variables (e.g. Bohm)

- Upper left field unattractive (no currently feasible proposals)

(e) Spontaneous collapse thys (e.g. GRW)

- You know GRW.

Difficulties:

- not Lorentz invariant
- predicts violations of energy conservation, which “is a little distressing (but then life is hard, you can’t please everyone!).” (629)

Putnam says: perhaps to (e)

(f) Many-worlds interpretation

- Putnam essentially looks at the DeWitt interpretation of Everettian many worlds.

Difficulties:

- Interpretation doesn't get the probabilities right; in fact, on this interpretation, QM would be "the first physical theory to predict that the observations of most observers will disconfirm the theory." (630)

$\Rightarrow$ Upper right corner is incoherent

Putnam says: no to (f)

(g) Hidden variables (again)

- Putnam retracts his earlier criticisms.

Difficulties:

- not Lorentz invariant
- not yet extended to QFT

Putnam says: perhaps to (g)

In conclusion (2005)

> *"What we are left with, if what I have said so far is right, is a conclusion that I initially found very distressing: either GRW or some successor, or else Bohm or some successor, is the correct interpretation—or... we will just fail to find a scientific realist interpretation which is acceptable." (631)*

(Don't pay attention to his speculations about quantum cosmology at the very end of article, I think they are misguided.)

A final bit of trivia

"[I]t took a long time for physicists to admit that there is a problem. I can tell you a story about that. In 1962 I had a series of conversations with a world-famous physicist (whom I will not identify by name). At the beginning, he insisted, 'You philosophers just think there is a problem with understanding quantum mechanics. We physicists have known better from Bohr on.'[suppressed footnote] After I forget how many discussions, we were sitting in a bar in Cambridge [(MA)], and he said to me, 'You're right. You've convinced me there is a problem here; it's a shame I can't take three months off and solve it.'

"Fourteen years later [(1976)], the same physicist and I were together at a conference for a few days, and he opened his lecture at that conference (a lecture which explained to a general audience the exciting new theories of quarks) by saying, 'There is no Copenhagen interpretation of quantum mechanics. Bohr brainwashed a generation of physicists.' Evidently, he had undergone a considerable change of outlook." (619)

“Niels Bohr brainwashed the whole generation of theorists into thinking that the job was done 50 years ago.” (Murray Gell-Mann, in Douglas Huff and Omer Prewett (eds.), The Nature of the Physical Universe*, 1976 Nobel Conference, New York, 1979, p. 29, also cited by Popper, Quantum Theory and the Schism in Physics, 1982, p. 10.)*

Figure: From: http://gustavus.edu/events/nobelconference/archive/

- *Max Delbrück
- René Dubos
- Sidney Fox
- Bernard M. Loomer
- Peter Marler
- Elizabeth Shull Russell

1976 (XII) - The Nature of the Physical Universe

- *Murray Gell-Mann
- Sir Fred Hoyle
- Stanley L. Jaki
- Hiliary W. Putnam
- *Steven Weinberg
- Victor F. Weisskopf

1975 (XI) - The Future of Science

- *Sir John Eccles
- Langdon Gilkey
- *Polykarp Kusch
- *Glenn Seaborg