Philosophy of Quantum Mechanics: Week 4

Philosophy of Science

> **Scientific realism**: Science aims to discover true facts about the (mind-independent) world, including those parts that cannot be directly observed, and we are justified in believing that it (sometimes, partially) succeeds in its aims.

Denying this claim is a strong move, but we can see why one might be inclined to make it: quantum systems look as if they don't have anything like classical properties, and there may be reason to doubt that their state is mind-independent.

For anti-realists, the aim of science is only to construct theories which are *empirically adequate*—theories which make all correct empirical predictions, i.e. which *save the phenomena*.

- For *verificationists*, a theory's claims about the unobservable are *meaningless*.
- On van Fraassen's *constructive empiricism*, we should be agnostic about the unobservable claims of a theory.

Recap: The Measurement Problem

Proposed realist solutions to the measurement problem include:

1. *Dynamical* collapse theories, e.g. GRW.
2. Insist that there really is some property of the system, not captured by the usual quantum state, that we're measuring that determines the outcome, so that the system is in a given state all along, and doesn't have to change discontinuously. (Deterministic hidden variable theories).
3. Try to find a way of making sense of quantum mechanics with *only* the unitary dynamics. (The Everett interpretation).

The Copenhagen Interpretation

The *Copenhagen interpretation* is not a well-defined term, but indicates a cluster of related views. Some common ground:

- Agree that there is an important difference between the classical and quantum regimes.
- Agree that the quantum state is the best we can do in describing the micro-world: the physics doesn't need changing.

All in some way question realism about QM. But there are many different positions:

1. Heisenberg: The wavefunction represents possibilia; measurement creates values.
2. Bohr: A Neo-Kantian (?) view of the role of the classical world.
3. Instrumentalism.

Heisenberg

The kind of view on quantum mechanics developed by Heisenberg is now very common amongst physicists—Peierls provides a good example. In summary:

- The quantum state does not represent anything real: instead it represents 'our knowledge' (non-rhetorical question: of what?). (In fact, Peierls is resistant to the notion of 'reality' *tout court*—hence he is clearly situated in the anti-realist camp.)
- Quantities such as position, momentum etc. only become meaningful on performing a measurement—at which point, the quantum state *collapses* (in the manner discussed).
- An irreducible role for life/consciousness: *this* is what instigates collapse.

Hard to make sense of this view... (Though that's not to say it can't be done.)

Bohr

Bohr's account does *not* employ collapse! (Howard p. 669) Moreover, it does *not* incorporate consciousness! (Howard p. 669) For Bohr:

- We can ascribe determinate properties to quantum mechanical systems.
- But only in the context of a given experimental scenario.
- Given different contexts, we ascribe different (classical) properties, but not at the same time. (e.g. position/momentum, or colour/hardness are 'complementary' observables).

Howard puts more meat on the bones:

- For Bohr, measurement is "just another species of physical interaction". (Howard p. 671)
- What's novel about measurement is that, as in any other quantum interaction, the post-measurement joint state of the object plus the measuring apparatus is *entangled*. (Howard p. 671)
- Only in such cases can we ascribe classical quantities to systems: One is permitted to speak of e.g. an electron's having a definite momentum only in a specified experimental context. (Howard p. 674)
- Bohr does not endorse the anti-realism often attributed to him (Saunders p. 3). He does not say that one cannot ascribe reality to quantum phenomena, only that one cannot ascribe an "independent reality" to the phenomena or to the "agencies of observation." His point is that, since the object and the apparatus form an entangled pair, they cannot be accorded distinct, separate realities. (Howard p. 671)
- Bohr did not assert that one describes "classically" all of and only that which stands on the instrument side of the cut. Instead, Bohr asserted that one describes "classically" those degrees of freedom of both instrument and object that are coupled in the measurement.

Should we still embrace Bohr these days?

> Bohr insisted that the formalism can only be interpreted by specification of a (classically defined) context of measurement. But there are now plenty of examples of causal spacetime explanations for the phenomena that Bohr considered (as given in all the major realist schools today, whether pilot-wave theory, GRW theory, or the Everett interpretation); and we have in decoherence theory technology for obtaining approximately classical descriptions from quantum ones that evade Bohr's strictures entirely. (Saunders pp. 24-25)

But there are still many who still express views akin to those of Bohr—e.g. Rovelli.

Van Fraassen

- If one is an anti-realist of van Fraassen's ilk, one is still committed to the literal interpretation of scientific theories (even if one is ultimately agnostic about the non-observational parts of the theory in question).
- Thus, for van Fraassen, there remains a burden to solve the measurement problem.
- So the measurement problem still has force against this brand of instrumentalist.