Anti-Haecceitism and Structuralism in Quantum Mechanics

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Abstract

In a recent paper, Adam Caulton and Jeremy Butterfield (forthcoming) argue that quantum mechanics (QM) supports a position they call 'structuralism.' Their argument is an update of Stachel's (2002) that draws on parallels between general relativity (GR) and QM to argue for a structuralist understanding of both theories. Caulton and Butterfield argue that Stachel's original argument is problematic because QM – as he develops it – is not analogous to GR in the relevant respects (here they echo the criticisms of Pooley (2006)), but that the analogy (and hence the argument) can be restored by a more complete understanding of QM. Specifically, the authors urge that once we allow for the possibility of paraparticles (or, more accurately, the denial of the symmetrization postulate), QM exhibits a feature known as 'anti-haecceitism' that bears a close resemblance to Leibniz equivalence in GR. On the basis of this analogy, Caulton and Butterfield argue that we should adopt their version of structuralism in the context of QM.

The arguments Caulton and Butterfield offer for anti-haecceitism in QM are convincing, but the version of structuralism they use it to motivate is surprisingly weak. They characterize the position as one whose "central claim is that individuality is grounded, if at all, only on qualitative properties and relations" (*ibid.*, 4). Thus, 'structuralism' on this view, is committed to using a version of the Principle of the Identity of Indiscernibles (PII) that considers only qualitative properties to determine what counts as an individual. Every thing must be either: (1) a qualitatively discernible individual (subject to the PII) or (2) a non-individual (not subject to the PII). Notice, however, that there is nothing particularly structuralist (in the intuitive sense)

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about either option. (1) could be realized by the Humean mosaic of David Lewis or the even the monads of Leibniz while (2) could be implemented by a metaphysics of primitively distinct non-individuals without any appeal to structure, relations or other kindred spirits. It is worth asking, then, whether anti-haecceitism in QM can motivate a thoroughly structuralist metaphysics.

I propose that it can. The metaphysical position Caulton and Butterfield argue for under the name 'structuralism' is really simply a restatement of anti-haecceitism rather than an explanation of it. If we want to know *why* anti-heacceitism is the case we need a deeper explanation. Such an account can be found in Healey's (1995) treatment of spacetime substantivalism in the context of GR. In this paper it is proposed that the best way to capture substantivalist intuitions about spacetime while preserving a commitment to Leibniz equivalence is to endow spacetime points with certain location properties *essentially*. Healey expresses this idea in terms of a principle called 'minimal essence' which holds that spacetime points "could not have had a usurper – a different point that has just the actual location properties of p, while p itself has different properties" (*ibid.*,302) Notice that this thesis is explicitly modal; it says there there is no possible world in which another point has the same location properties as p while p has different ones. This is why the view is a version of essentialism about spacetime points.

The view is also 'structuralist' in a straightforward sense. Minimal essence follows from a conception of spacetime points that views them as nothing more than places in a relational structure, a view closely aligned with mathematical structuralism (Shapiro (1997)) and non-eliminative varieties of ontic structural realism (see Chakravartty (2011)). Most importantly, this view grounds Leibniz equivalence in a solid metaphysical foundation: the reason models related by a diffeomorphism represent the same physical state of affairs is that spacetime points *simply aren't the kinds of things that can have different location properties from the ones that actually posses.* In other words, the essential properties and relations of spacetime points render swapping them in a physical sense impossible, so we are forced to regard the apparent swapping as redundant representation of the same state of affairs.

One conclusion of Caulton and Butterfield's paper is that GR and QM share a common sort of underdetermination; each theory provides distinct representations for the same state of affairs that differ

with respect to "which object is in which place." This suggests that if Healey's minimal essentialism successfully explains Leibniz equivalence in GR, it should also make sense of anti-haecceitism in QM. Indeed, if we apply his thesis to quantum particles, we find a promising structuralist explanation of anti-haecceitism. The story goes roughly as follows. Quantum particles occupy a certain place in the relational structure provided by the theory essentially; the relational properties attributed to them on the basis of their quantum state (state-dependent properties) are *essential* properties common across all possible worlds in which they exist. Hence, representations of quantum states that differ only with respect to which particle is where in the relational structure cannot be regarded as depicting distinct physical states of affairs because such alternative are blocked by the essential properties of the particles allegedly being permuted. Such a metaphysics provides a satisfying structuralist explanation of the puzzling phenomenon of anti-haecceitism in QM.