Title: Ontic Structural Realism and Quantum Mechanics

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(i) particles are not taken to be individual entities because they are not distinguishable; and, (ii) entanglement is taken to be relational structure that does not reduce to the state of parts and their causal interactions.

Furthermore, the idea of modal structure in OSR is exemplified by the way quantum mechanics sits between Bell-inequality violation and no-superluminal signalling. However, what should the advocate of OSR say about the measurement problem and decoherence? Wallace and Saunders combines OSR with Everettianism and argue that they need each other. Are Ladyman and Ross justified in their reluctance to agree with him?

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28th May 2021

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Ontic structural realism is a form of scientific realism based on quantum mechanics in two ways: (i) particles are not taken to be individual entities because they are not distinguishable; and, (ii) entanglement is taken to be relational structure that does not reduce to the state of parts and their causal interactions. Furthermore, the idea of modal structure in OSR is exemplified by the way quantum mechanics sits between Bell-inequality violation and no-superluminal signalling. However, what should the advocate of OSR say about the measurement problem and decoherence? Wallace and Saunders combines OSR with Everettianism and argue that they need each other. Are Ladyman and Ross justified in their reluctance to agree with him?

Preface

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very many thanks to Steve French under whose tutelage and with whom I developed Ontic Structural Realism originally, and to Don Ross for more recent collaboration especially on our book *Every Thing Must Go*.

Ontic structural realism (OSR) downgrades objects in favour of relational structure.

OSR may be regarded as different to scientific realism, or as a version of it, depending on what the latter is taken to be.

OSR is differentiated from van Fraassen's Structural Empiricism, by incorporation of natural necessity.

OSR is supported by a consilience argument.

Triangulation

George Davey-Smith and Marcus Munafo say "strong theories emerge from the synthesis of multiple lines of evidence".

John Herschel, Preliminary Discourse on the Study of Natural Philosophy (London, 1830):

> *...the surest and best characteristic of a well-founded and extensive induction . .. is when verifications of it spring up, as it were, spontaneously into notice, from quarters where they might be least expected, or even among instances of that kind which were at first considered hostile to them. Evidence of this kind is irresistible and compels assent with a weight which scarcely any other possesses...*

The Problem of Theory Change

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It is often framed in terms of the abandonment of central theoretical terms like 'caloric', 'ether' and 'phlogiston'.

But the problem of theory change is not solved by finding plausible referents for abandoned terms like 'ether'.

Consider the relationship between classical and quantum physics, or between Newtonian and relativistic physics.

From our current perspective the ether has much more in common with the field, than atoms do with the indivisible particles of antiquity (Stein 1989).

Sructural Realism

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This confirms Poincaré's idea of physics as ruins built on ruins in the sense that the old theories form the foundations of the new ones rather than the ground being cleared before work begins.

The key point is that more than the empirical content and phenomenological laws of past theories is retained.

For example, it is not just Kepler's laws and Galileo's kinematical laws that are preserved as limiting cases of general relativity, but the Newton's inverse square force law that unifies and corrects those laws is retained in the form of the Poisson equation as a low-energy limit of Einstein's field equation.

The laws take mathematical form and there are special cases, such as that of Fresnel's equations, where the very same equations are reinterpreted in terms of different entities.

However, of course this is not the norm, and in many cases mathematical structure is lost and radically modified on theory change.

OSR does not require that all mathematical (or any other kind of) structure is preserved on theory change.

Modal Structure

OSR is not pure structuralism as van Fraassen charges because it is realism about the modal structure of the natural world.

Kuhn and Feyerabend popularized the view that theory change in the history of science disrupts narratives of continuous progress and realism.

Noretta Koertege (1968) considered phlogiston theory as an example supporting the general correspondence principle because the well-confirmed empirical regularities stated in terms of phlogiston theory (such as that air saturated with phlogiston by combustion does not support respiration) are true when translated into the language of oxygen (de-oxygenated air does not support respiration).

Furthermore, and crucially for structural realism, the fact that combustion, respiration and calcination of metals are all the same kind of reaction and there is an inverse kind of reaction too is an example of a theoretical relation that is retained from phlogiston theory.

Even though there is not such thing as phlogiston, the tables of affinity and antipathy of phlogistic chemistry express real patterns that we now express in terms of reducing and oxidising power.

The examples from mathematical physics cited above, and the case of phlogiston theory show that even though the ontology of science may change quite radically at the level of objects and properties (for example, there is no elastic solid ether, no phlogiston and no caloric), there can be continuity of the modal structure that is attributed to the world.

Selective Realism

Stathis Psillos (1999), sought to solve the problem of theory change by what David Papineau dubbed 'selective realism' (1996), which involves analyzing case studies from the history of science to find a formula that restricts the epistemic commitment of scientific realists to parts of theories that will be retained.

The idea is that close examination of the history of science will reveal what it is about abandoned theoretical constituents that distinguishes them from those that are retained, so that a selective commitment to current theories can be then be applied in the confidence that the relevant ontology will not subsequently be abandoned.

Ontic Structural Realism as Triangulation

Worrall framed structural realism is epistemic terms following Poincaré who said we can only know relations.

Worrall was concerned with the scientific realism debate in general philosophy of science, but French wanted a form of realism that could account for the problems of identity and individuality in quantum physics and spacetime physics.

Physics is highly mathematicised as described by Max Planck.

Quantum mechanics seems to involve relations that do not supervene.

OSR in the philosophy of physics involves inflating the ontological priority of relational structure and can be applied also to spacetime physics or quantum field theory.

The Modal Structure of Entanglement

Consider the example of entanglement.

Ghisin and Popescu proved that that pure entangled states always make for violation of a Bell-type inequality.

What such violation amounts to is that the relative frequencies for repeated measurements do not accord with the correlation functions derived from local hidden variable models.

Bell's Theorem and its generalisation are not about quantum mechanics, but about the modal structure of the world (cf. PR boxes).

Modality and the arguments for scientific realism

The main motivation for scientific realism in general and structural realism in particular is the no-miracles argument which makes no sense without necessity tying things together.

probability and statistics

The implementation of computation and information is modal.

Equilibrium explanation is scientific explanation but not causal explanation:

> *Where causal explanation shows how the event to be explained was in fact produced, equilibrium explanation shows how the event would have occurred regardless of which of a variety of causal scenarios actually transpired. (Sober [?], p.)*

Symmetry explanation

Ontological Problems for Scientific Realism

- scientific realism and common sense realism