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The ontology of quantum field theory: Structural realism vindicated?

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ABSTRACT

In this paper I elicit a prediction from structural realism and compare it, not to a historical case, but to a contemporary scientific theory. If structural realism is correct, then we should expect physics to develop theories that fail to provide an ontology of the sort sought by traditional realists. If *structure alone* is responsible for instrumental success, we should expect surplus ontology to be eliminated. Quantum field theory (QFT) provides the framework for some of the best confirmed theories in science, but debates over its ontology are vexed. Rather than taking a stand on these matters, the structural realist can embrace QFT as an example of just the kind of theory SR should lead us to expect. Yet, it is not clear that QFT meets the structuralist's positive expectation by providing a structure for the world. In particular, the problem of unitarily inequivalent representations threatens to undermine the possibility of QFT providing a unique structure for the world. In response to this problem, I suggest that the structuralist should endorse pluralism about structure.

1. Introduction

Broadly construed, structural realism (SR) is the thesis that our best scientific theories tell us only about the *structure* of the world. This is to be contrasted with traditional scientific realism, which attempts to find a complete ontology of individual objects and properties in scientific theories. Cast in this way, SR is a form of selective skepticism toward scientific theories; we should regard theories as approximately correct about the structure of the world but have an attitude of skepticism toward everything they (apparently) attribute to the world beyond structure.[1]

In this paper I will be concerned with two main questions. In Section 2, I will ask what SR should lead us to expect. If SR is the correct view of scientific theories what follows? Here I will argue that SR should lead us to expect that future scientific theories (or at least theories of fundamental physics) will not provide an ontology of individual objects and properties as sought by traditional realists. If it is indeed *structure alone* which our best scientific theories are tracking, then we should expect ontological posits that go beyond structure to fall by the wayside.

In Section 3, the question at issue will be whether SR is vindicated. Is there reason to think that science is developing theories that fail to provide a traditional ontology? I will argue that there is good reason to think quantum field theory (QFT) fulfills this expectation. Despite a concerted effort by philosophers of physics, an ontology of individual objects and properties—of the sort sought by traditional realists—has not been forthcoming in QFT. This should be troubling for the traditional realist, but is just what the structuralist expects.

SR makes a positive prediction as well: theories *should* provide us with a *structure* of the world. Here the case of QFT is not so easily embraced by the structural realist. In fact, QFT seems just as unable to provide us with an unequivocal structure as a traditional ontology. After outlining several responses to this problem, I suggest that SR may embrace a pluralism about models to resolve the issue.

2. What structural realism predicts

2.1. Structure and success

Following Worrall (1989), SR aims to be the "best of both worlds" by both accounting for theory change in science and providing an explanation for the instrumental success of individual scientific theories. Much work has focused on the first component: does a commitment to only structure allow the realist to sidestep antirealist arguments such as the "pessimistic metainduction"? But

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[1] Ontic structural realists such as James Ladyman and Steven French regard knowledge of the structure of the world as in principle complete, and hence, there is no room for skepticism on their view. Rather, the ontic structural realist takes the ontology of the world to be fundamentally structural. This means that the correct attitude toward the putative objects and properties recognized by traditional scientific realists is atheism, not skepticism.

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one may also wonder how SR is able to account for success in science.

Here the structural realist may adopt a strategy deployed by traditional realists.

> If scientific realism is to be plausible and … in agreement with actual practice, then it must go for differentiated commitments to scientific theories, and what they entail about the world, in accordance with the evidence which supports them. (Psillos, 1999, 161)

Psillos goes on to argue that the ontological commitments of the realist are limited to those entities responsible for the novel predictive successes used to motivate realism with respect to some theory. This suggests a strategy—letting the drivers of empirical success determine ontological commitment—that may be borrowed by the structural realist with the addendum that *structure alone* is responsible for empirical success. Steven French describes this approach in his recent book:

> The structuralist also focuses on the relevant success-inducing structures presented by the theory. However, instead of taking these to be the metaphysical outcome of properties and their interrelations [as the traditional realist does] … she takes these structures themselves to be fundamental … (French, 2014, 44)

To illustrate, French uses the often discussed example of Frensel's wave theory of light. In this case, the structural realist argues that we should be committed to that which is responsible for the theory's empirical successes, namely, Frensel's equations and the structure they encode. Of course, defending the structuralist's claim that structures alone are responsible for empirical success may prove difficult. But my intention here is more limited: I wish to ask what follows from such a claim.

In particular, I want to highlight that for the structural realist adopting this strategy, structure is *doing all the work* in our scientific theories. Regardless of whether we follow Psillos' emphasis on novel predictive success, the structural realist must claim that structure alone is capable of accounting for empirical success. This is simply a result of the structuralist's desire to make use of the "no miracles" argument for scientific realism. If structural realism is to provide a suitable explanation for success, then it had better be sufficient for that in which empirical success consists. Perhaps the claim that structure is sufficient for success is made more plausible if empirical success is limited to novel predictive success, but this needn't be a commitment of structural realism. What *is* a commitment of structural realism is that structure alone—and not objects that may be posited over and above it—is all that is needed to account for the empirical success of those scientific theories worthy of belief.

Given this, it may appear as something of a mystery why some scientific theories seem to present us with *more* than structure. Why, for example, does classical mechanics seem to posit fundamental objects—in the form of Newtonian particles—in addition to the structures provided by the theory?[2]

One explanation open to the structural realist is that the traditional ontology associated with some scientific theories plays a merely heuristic role.[3] Newtonian particles, for example, might not correspond to any individual objects in the world, but rather allow one to conceive of the structure of the classical world. Indeed, it might prove difficult to understand and apply a scientific theory without there being *some* basic ontology of objects and properties in the context of which its claims are cast. The structural realist can readily grant this point without being committed to the reality of such an ontology. As an analogy, consider a mathematical structuralist who recognizes that doing arithmetic is simplified by thinking in terms of numbers qua objects, but takes the natural-number *structure* as the proper subject matter of the field.

For my purposes, it doesn't much matter how the structural realist accounts for apparent ontological posits that exceed structure in certain scientific theories. Regardless of the particular explanation offered, SR views the surplus ontology of a scientific theory as a *defect*, at least as far as the theory's perspicuity is concerned. According to the structural realist, the reason why our best scientific theories are successful is that they (more or less) accurately reflect the structure of the world. Any ontological commitments that extend beyond structure must be regarded as surplus content.

2.2. Surplus content in physics

There is a reading of the history of physics as an elimination of surplus content. Consider, for example, the development of spacetime theories. Newton posited absolute space and time, but the dynamics encoded in his laws did not require a privileged inertial frame. The empirical success by Newton's theory is not the result of absolute space, because it is unaltered when one switches to a conception of spacetime that does away with a privileged inertial frame (Galilean spacetime). In the next major revolution in spacetime physics, the special theory of relativity did away with absolute positions and times altogether. Obviously there is far more to the story, but this rough sketch illustrates a trend toward the elimination of aspects of theories that are surplus in the relevant sense; idle wheels that do no work tend to be abandoned in future theories. Jenann Ismael and Bas van Fraassen describe this trend as follows:

> The ontologies of our most fundamental theories are not guided by physical intuition; they are not shaped by philosophical prejudices, but led, at their best, by the ideal of a kind of formal simplicity. The history of modern physics has been … 'a long, sustained effort to shed redundant concepts' (Ismael & van Fraassen, 2003, 391)

Of course, the elimination of surplus content from physical theories is not always without costs. Scientific theories that are more sparse in their posits may lack the resources necessary for their successful application. Returning to the case of spacetime theories, there are two ways of understanding the metaphysical change brought about by relativity. We may, as I suggested above, claim that relativity *eliminates* positions and times and all absolute kinematic quantitates that depend on them. Tim Maudlin, for example, urges that "[t]o understand Relativity, we have to expunge all ideas of things having speeds, including light" (Maudlin, 2012, 68). Yet, the common "textbook" presentation of (special) relativity *does* make use of speeds and related quantities, but relativizes them to pragmatically chosen frames of reference. If one is interested in applying relativity, then it is extremely helpful

[2] There are several candidate structures available in classical mechanics. One natural choice for the structural realist is to focus on state-space structure. North (2009), for example, argues that classical physics ascribes Hamiltonian (or symplectic) structure to the world while, Curiel (2014) argues instead for a Lagrangian state-space structure. SR claims that such structures—and not any objects thought to exist over and above them—are the proper target of the realist's ontological commitment.

[3] French refers to this strategy as "Poincaré's Manoeuvre" (French, 2014, 67).