

## **Author Response to Referee's comments:**

### Referees:

1. What, exactly, is the relationship between physics and metaphysics that the author, and/or the PO approach, assumes? I have the impression that a weird (and hardly plausible) “post-positivist” notion of metaphysics is being assumed here, in which physical theories saying nothing about what the world is like are proposed (based, presumably, on empirical evidence) and then it is the job of metaphysicians to come along and say something about what, according to the proposed theories, the world might actually be like. This, I suspect, is indeed how some philosophers of physics see their role. (We do, after all, live in a post-positivist world.) But I think this is absurd, and indeed contrary to the PO approach the author means here to clarify and endorse. Physics theories ought to say something about what the world is like! That, I take it, is a fundamental tenet of the PO approach. But then it seems that the point of the PO approach isn't really, as the author describes it at one point, to show us how physics theories with clear ontologies “can be used as a guide to metaphysics”. Rather, in my opinion, the metaphysics is the primary thing: it is a metaphysical doctrine (along the lines of “matter in three-dimensional space really exists and is what all of our empirical evidence is ultimately \*about\*”) which undergirds the PO approach's insistence that “any fundamental physical theory [have] a well-defined architecture, [at] the foundation of which there is the [PO], which represents matter.” Put it this way: it seems to me that the PO approach is fundamentally \*normative\* -- it is not telling us what architecture physical theories do (historically/naturalistically) have, but rather telling us what architecture physical theories \*should\* have. And this “should” is based on certain metaphysical commitments. So, it seems to me, the PO approach isn't fundamentally about how to extract metaphysics from physical theories; it is rather about how a certain set of metaphysical commitments leads us to demand that proper physical theories should have a certain architecture. I just think the whole idea would be clearer if this overall relationship among physics, metaphysics, and the PO approach, were straightened out.

### Author:

I have added a section to explain what the relationship is between physics and metaphysics. It is brief, but hopefully it will make clearer what the commitments are. I also have made changes here and there to address the referee's concerns raised in point 1.

### Referee:

2. At one point the author describes the notion of primitiveness (in “PO”) by saying: “some part of the ontology is `more important' than other parts.” I find this (and related) formulation(s) problematically ambiguous. Are the parts of the ontology that are selected out as constituting the PO “more important” in a metaphysical/physical sense? That is, is it that the non-primitive elements of the ontology have some kind of secondary existence? Or is it instead that the PO is “more important” in some kind of epistemic sense, e.g., the primitive ontology is what we are somehow most directly aware of (in sense perception?) as against the non-primitive elements which are invisible (and hence have to be somehow inferred from complex abstract chains of reasoning)? If the former, I am skeptical, since I don't know what it could possibly mean for two things to both really exist, but for one of them to be somehow metaphysically “more important” (more real??) than the other. (This worry is mentioned very briefly, alongside some others, in section 10; but to me the entire approach remains somewhat vague, confusing, unclear until this is explicitly addressed.) On the other hand, if the sense of primacy here is merely epistemic, I

then don't see how certain of the suggested implications (like that the non-primitive elements of the ontology can be thought of as having a nomological character) would follow or even relate. On these points, I would find it clarifying to see a concrete discussion, not just of classical particle mechanics and then quantum mechanics, but also of classical electrodynamics (CED). I gather that the ontology of CED includes (charged) particles as well as electric and magnetic fields. Which of these are part of the specifically \*primitive\* ontology? It is not clear to me, and all the possible answers seem to raise worthwhile questions. For example, the idea that the primitiveness of the PO is (basically) epistemic might suggest that the particles are the PO, and the fields are non-primitive. Does it then follow that electric and magnetic fields are not fully real, or not real in the same way that charged particles are real, or have a nomological (rather than a "material-field-ish") character? (The author says in passing that electromagnetic fields can "arguably" be taken as part of the PO; but I have also heard advocates of the PO approach say that at least the magnetic field should not be considered part of the PO.) To me the PO approach starts to seem slightly awkward and cumbersome and ill-fitting in the context of this example (which in turn suggests to me that the PO approach is not really a kind of universal perspective on physical theories, but is instead just motivated by the particular concerns arising in quantum theory – in particular the fact that the quantum wave function, unlike the fields of CED, cannot really be understood as "material" at all because it doesn't live in three-dimensional space). But I would love to be proven wrong by a fuller discussion of this and/or other helpful concrete examples. (What other examples? I also find the idea of treating momentum, in classical mechanics, as a non-primitive part of the ontology, somewhat puzzling. It seems we have some kind of direct sensory access to (average?) momentum, in the form of temperature. Should I conclude, after all, that the PO is primitive in a physical/metaphysical sense, rather than an epistemic one? So that might warrant further discussion. How about neutrinos? Are they part of the PO of standard particle theory? Higgs fields? Why? Why not? And re: physical equivalence, if the fields in CED aren't part of the PO, does that make CED and Wheeler-Feynman physically equivalent? For me these sorts of questions deserve answers.)

Author:

I have expanded the sections in which I discuss the idea behind the PO approach and the requirements for a variable to be a good PO. I have better explained and spell out the different meaning of "primitive" in the primitive ontology. Also, I have added a section in which I discuss classical electrodynamics, in which I contrast the notion of PO with the one of local beable.

Referee

3. Since "MW" (i.e., Everettian) approaches are so popular, I would find it helpful to actually engage a bit more seriously with its proponents in this paper, instead of just dismissing it as "incompatible with the PO approach". Explain, briefly, why the Everettians don't think they \*need\* a PO in their theory in order to achieve empirical adequacy. Explaining more about how and where and why PO-ism and Everett-ism fail to see eye to eye, will help make the PO approach (and its underlying assumptions and motivations) clearer.

Author:

I have addressed this issue in a (long) footnote.

Referee:

4. I find the tangents about purely notational issues (e.g., the semi-colon, and the example of denoting classical mechanics as  $x_{\text{deterministic}}^{\text{deterministic}}$ , and basically all of section 11) sort of pointless and distracting. The intended audience for a paper like this shouldn't be made to worry about notation. Pick a notation that gets the point across clearly and don't let it become the focus.

Author:

I have relegated the new notation to a footnote.

Referee:

5. I didn't understand the reference in footnote 8 to "a theory like this with a [PO] of wave functions". What theory? Did the author actually mean wave functions, or "fields, i.e., extended objects"? These are not really the same thing – and indeed, not even possibly the same thing, which is precisely why the author (in my opinion, correctly) insists that the wave function "is not a suitable primitive variable."

Author:

I modified the footnote accordingly.

Referee:

6. I noticed a couple of ungrammatical pseudo-sentences, as in: "To specify what the ontology of a theory is amounts to select, among all the variables of the theory, are to be taken as representing what exists in the world."

Author:

Thanks, I have tried to fix as many other mistakes as I could find!

Referee:

7. The paper ends rather abruptly. Maybe a final section to summarize / conclude?

Author:

I have added a final section to this purpose.