Review of Alyssa Ney's

The World in the Wave Function: A Metaphysics for Quantum Physics

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There is not much of a consensus on almost anything about quantum mechanics. I take it, however, that the minimum consensus is that *although quantum mechanics is empirically successful, quantum mechanics is hard to understand*. Quantum mechanics, in the way it is presented in most textbooks, does indeed not provide a clear picture of reality that would make it a theory to be understood.[1] In her new book, *The World in the Wave Function: A Metaphysics for Quantum Physics,* Alyssa Ney tries to make this blurry picture of reality more precise, even if this picture will turn out to be heterodox and unfamiliar.

The book aims at defending *wave function realism*. This name may not be the best choice to capture the essence of this view, as other interpretations also claim to be realist with respect to the wave function (as Ney mentions on p. 62). Nonetheless, this notion is now entrenched to describe the following metaphysical picture: the wave function is a genuine physical field in configuration space, which is the fundamental space of the world. (You can imagine configuration space to be a space of very high dimensions, in which every point is normally interpreted to represent the positions of all the particles in the universe.)

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[1] Philosophers have developed systematic accounts of understanding, for example de Regt (2017). I present my own account of understanding physics in Hubert (2021).

The book gradually reveals the richness of this proposal. What kind of field is the wave function (Ch. 2 & 3)? How can wave function realism be extended to relativistic quantum mechanics (Ch. 4)? How do facts in configuration space explain facts in three-dimensional space (Ch. 5)? How is it possible that we perceive macroscopic objects in a space of three dimensions (Ch. 6 & 7)?

Ney repeatedly emphasizes that wave function realism is not to be conceived as one particular interpretation of quantum mechanics, but rather as a *framework* for different interpretations. The Everett interpretation and the spontaneous collapse theories seem to be particularly suitable for this framework. The different interpretations of quantum mechanics as they stand are much clearer about the ontology than textbook quantum mechanics, but there is still room for greater precision about the nature of the wave function.

I thought that the book would at first take down standard quantum mechanics and epistemic interpretations of the wave function, and argue for a general realist approach to quantum mechanics concluding that wave function realism is the best possible interpretation of the wave function. The dialectic of the book, however, is different. Ney *presupposes* a realist approach to quantum mechanics and presents wave function realism as a plausible candidate for such an approach, without highlighting the flaws of the competition. As Ney writes (pp. x–xi), “my stance in this book will be one of humility and tolerance for other approaches.”

Early in the book (in Ch. 2), we can experience the virtues of humility and tolerance. Ney and other philosophers used to argue that “if one wants a realist interpretation of quantum mechanics, then the phenomenon of quantum entanglement forces wave function realism on one.” (p. 49) Ney, however, grants in the book that this argument is not conclusive, as many other interpretations of the wave function can comprehensively explain quantum entanglement. Wave function realism is not the only game in town.

What are the best arguments in favor of wave function realism according to Ney? Wave function realism is distinguished from all its (realist) competitors, like, for example, the primitive-ontology approach (Allori et al. 2008), space-time state realism (Wallace and Timpson 2010), or the multi-field account (Hubert and Romano 2018), by offering a metaphysics that is separable and local. These notions often get conflated, and the book does a good job at separating them. In previous work, I called separability *ontological locality* and locality *dynamical locality* to show where the main difference lies between these two notions (Hubert and Romano 2018). Separability describes the ontology of the wave function: roughly speaking, the wave function is separable in configuration space because if we chop up configuration space into arbitrary small pieces each of these pieces has a well-defined distribution of field values and sticking together these pieces will give us the entire wave function. The wave function is not separable in three-dimensional space. If you point with your finger somewhere in three-dimensional space and ask me to tell you what the value of the wave function is there, I cannot (in general) do so. On the other hand, if you had a configuration-space finger and point somewhere in configuration space, I can give you the values of the wave function for each region. The book makes an excellent case that wave function realism offers a truly separable ontology and defends it against common challenges.

The book gets a bit harder to follow when it talks about locality. I think that is for two reasons. First, the book transitions from separability to locality by discussing a disagreement about whether John Bell substantially changed his definition of locality over time. I do not see how this particular debate about subtle nuances in Bell's work is needed for developing locality in configuration space. I fear that the reader might get lost here in some intricate details that are only tangential to the actual problem. Second, Ney ties locality to causality, "locality, in the sense to be discussed here, is a causal notion, tracking facts about the *causal* determination of events." (p. 96) We can spot the problem of this connection in an example discussed in the book (section 3.7). Let's apply wave function realism to the GRW collapse theory, and let's say that the wave function before it collapses has only two lumps in regions *A* and *B* (in configuration space) separated far away from each other. Then the wave function collapses and is only concentrated in region *A*. The collapse by itself occurs spontaneously, that is, it is not determined by external circumstances. But does that mean that there is no causal relation between the lumps in region *A* and *B when the wave function collapses*? And even if we deny such a causal relation, isn't there at least some instantaneous change of the wave function over far away distances? Isn't that some form of non-locality? Wave function realism by itself, therefore, cannot determine whether quantum mechanics is fully local. One also needs to carefully analyze the particular interpretation of quantum mechanics included with it—as Ney does in chapters 3, 4, and 5 for the GRW collapse theory, the Many-Worlds theory, Bohmian Mechanics, and relativistic quantum theories.

Wave function realism interprets the wave function as a separable object in configuration space which may have a local dynamics in this very space (at least when applied to the Many-Worlds interpretation, in which the wave function does not collapse). What are the advantages of this metaphysics? Ney dedicates a whole section to answer this question (section 3.9). I particularly like this section because it shows again how humility can give rise to a nuanced, honest, and fruitful discussion. Ney debunks several arguments to defend locality (in three-dimensional space): (i) locality is demanded by special relativity, (ii) locality is a prerequisite of empirical science, (iii) a separable and local metaphysics is needed to explain our direct experiences which appear to be separable and local. Two arguments remain for Ney to make the case for separability and locality: they are simple and intuitive.

I grant that separability and locality by themselves are intuitive. But is a separable and local metaphysics *in configuration space* more intuitive than a metaphysics *in three-dimensional space* that is not so? An alternative that actually shares a lot with the general methodology of wave function realism is the primitive ontology approach or the theory of local beables—both postulate a separable ontology in three-dimensional space. But when reading the book, one may get the impression that these approaches are incompatible with wave function realism—an entire chapter (Ch. 5) is dedicated to arguing against local beables. John Bell, who coined the term *local beables*, argued that if the wave function is a non-local entity in three-dimensional space, some other local objects must exist. That is for two reasons: (i) local beables explain how macroscopic objects are constituted and how they behave, and (ii) local beables explain (in principle) our perception of these objects. One may argue that local beables are not necessary to do so, but local beables provide a simple and straightforward explanation. The wave function realist takes separability and locality as necessary conditions for metaphysics, a primitive ontologist (or a local beablist) may use them as guiding principles but settles for a compromise ontology balancing separability with non-separability and locality with non-locality. On the other hand, a wave function realist is the purest adherent to local beables, as the *entire* metaphysics consists of local beables in configuration space, namely, the field values of the wave function for every point of configuration space.

The challenge wave function realism—finally—faces is to account for the existence and behavior of macroscopic objects in three-dimensional space. If one starts with local beables in three-dimensional space, this task is easily accomplished. The local beables are the mereological parts of macroscopic objects and the role of non-local entities is to determine their behavior. The wave function realist may say that our perception of objects in three-dimensional space is some form of illusion. Certain parts of the wave function become conscious and have mental experiences; these experiences are somehow correlated with the behavior of the wave function, but there is no causal relation, and nothing more needs to be explained. Such a view may be called *wave function monadology.* The book does not go this route; it gives an account of three-dimensional space and objects therein in the last two chapters. This is probably the most original and most revisionary part of the book.

This account takes two steps: first, derive the existence of particles in three-dimensional space, and, second, explain how these particles make up macroscopic objects. The bulk of the metaphysical work is done in step one, which itself is divided into three parts: (a) symmetry properties of the wave function indicate the existence of particles, (b) the particles are mereological parts of the wave function, and (c) the particles are partially instantiated according to the strength of the amplitude of the wave function. There is a lot to be said about each of these steps, but I only want to briefly comment on (b). Although the particles are mereological parts of the wave functions, they are *not* located in configuration space. To accomplish this, Ney revises the notion of a mereological relation: *the parts do not need to share the same location as the whole*. I'm not sure whether that is a valid option for the mereological relationship of two physical objects. I can imagine, however, that this view may be inspired by the relationship between the mind and the brain: the mind is some part of the brain, but it is hard to pin down where exactly my mental experiences are. If that is the way to think about this revisionary mereology, then wave function monadology would fulfill the same standard as Ney's wave function realism, since the particles represented in the mind of the conscious parts of the wave function would be parts of the wave function although not at the same location. So by means of this kind of mereology, the ontological status of particles and of three-dimensional space becomes rather unclear in wave function realism. Where are these particles if they are neither in the wave function nor in somebody's mind?

The World in the Wave function is the most comprehensive examination of wave function realism up to now. It carefully examines arguments in favor of and against this metaphysics concluding that wave function realism is a tenable and consistent metaphysical picture of the world. What makes quantum physics so weird is its ontology in configuration space. I think this book has successfully shown that this kind of quantum weirdness can indeed be understood…at least, to some degree.

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References

Allori, V., Goldstein, S., Tumulka, R., and Zanghì, N. (2008). On the common structure of Bohmian mechanics and the Ghirardi-Rimini-Weber theory. *The British Journal for the Philosophy of Science*, 59(3):353–89.

de Regt, H. W. (2017). *Understanding Scientific Understanding*. Oxford: Oxford University Press.

Hubert, M. (2021). Understanding Physics: ‘What?’, ‘Why?’, and ‘How?’. *European Journal for Philosophy of Science*, 11(3):1–36.

Hubert, M. and Romano, D. (2018). The wave function as a multi-field. *European Journal for Philosophy of Science*, 8(3):521–37.

Wallace, D. and Timpson, C. G. (2010). Quantum mechanics on spacetime i: Spacetime state realism. *The British Journal for the Philosophy of Science*, 61(4):697–727.