Some Remarks on Wave Function Monism

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Abstract

Is wave function monism, the view that the wave function completely describes physical objects, a sensible view? GRW, one candidate to solve the measurement problem, might be taken to be an example of such view. I argue in this paper that it not so obviously so. I first show that a bare version of wave function monism is impossible, and even if one can construct monistic theories with additional rules (but no additional ontologies), they are not to be taken seriously. Instead, a preferable choice is that of a quantum theory in which physical objects are represented by entities in three–dimensional space or in four-dimensional space-time.

1 Introduction

Let us define *wave function monism* as the view according to which the wave function mathematically represents, in a complete way, fundamentally all there is in the world. Can and should we take such a view seriously?

Erwin Schrödinger was one of the first proponents of such a view, but he dismissed it after he realized it led to macroscopic superpositions for a wave function evolving in time according to the equations that has his name. The common wisdom is that to fix the problem of such superpositions there are two alternatives: "either the wave function, as given by the Schrödinger equation, is not everything, or is not right" [Bell 1987]. The deBroglie-Bohm theory, now commonly known as Bohmian Mechanics[1], takes the first option:

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[1]This theory has been presented for the first time by Louis deBroglie [deBroglie 1928] and later developed by David Bohm [Bohm 1952]

the description provided by a Schrödinger-evolving wave function is supplemented by the information provided by the configuration of the particles. The second possibility consists in assuming that, while the wave function provides the complete description of the system, its temporal evolution is not given by the Schrödinger equation. Rather, the usual Schrödinger evolution is interrupted by random and sudden "collapses". The most promising theory of this kind is the GRW theory, after the scientists that developed it: Gian Carlo Ghirardi, Alberto Rimini and Tullio Weber [Ghirardi *et al.* 1986].

It seems tempting to think that in GRW we can be wave function monists and avoid the problem of macroscopic superpositions just allowing for quantum jumps.

In this paper I first argue that "bare" wave function monism is not possible. That is, we need more structure than the one provided just by the wave function. As a response, monistic theories can be produced with such an additional structure, but without this addition being ontological in nature. I argue in reply that such "dressed-up" versions of wave function monism are not sensible, since they compromise the acceptability of the theory as a satisfactory fundamental physical theory. Therefore I maintain that:

- Strictly speaking it is not possible to interpret GRW monistically as a theory about the wave function only;
- Even if the wave function is supplemented by additional non-ontological rules, there are reasons not to take the resulting theory seriously.

Following the work in [Bassi *et al.* 2003], [Benatti *et al.* 1995], [Goldstein 1998], [Dürr *et al.* 1997], [Allori *et al.* 2008], and [Allori 2007], I maintain instead that it is better to regard GRW in particular, and any fundamental physical theory in general, as theories in which physical objects are represented by a mathematical object in three–dimensional space or in space-time.

2 Bare Monism

In the following I present bare monistic GRW, discuss its problems and the proposed solutions.

One of the main proponents of a monistic interpretation of GRW is David Albert. He maintains that the wave function represents a real, physical field, "just like electromagnetic fields in classical electrodynamics" [Albert 1996]. One difference, though, is that the wave function lives in a much bigger space than three–dimensional space: it lives in a space that combines all the positions of all the particles in the universe. So, if there are N particles in the universe, this space – called configuration space – has dimension $M = 3N$. This is what physical space really is. "And whatever impression we have to the contrary (whatever impression we have, say, of living in a three-dimensional space or in a four–dimensional space–time) is somehow flatly illusory" [Albert 1996].

Clearly, not only it seems possible but also very natural to interpret GRW as a theory about the wave function: Isn't it the case that in the theory there is just one fundamental equation that involves the wave function? And isn't it the case that when similar situations have happened in previous fundamental physical theories (like classical mechanics) we interpreted those entities as representing physical objects?

On the other hand, there are some problems. First, the fundamental space is not the usual three–dimensional space anymore: rather, it is configuration space. So we need to explain why it appears *as if* we live in a three–dimensional space. Under the current assumption, we do not have enough resources to get three–dimensional space without making use of the very definition of configuration. In fact, if the theory concerns the behavior of *stuff* in this space of dimension M, then the whole world is just mathematically represented by a function in that space: the wave function is $\psi(q)$, where q belongs to $\mathbb{R}^M$. We might be tempted to regard the coordinates of q as grouped into triples, representing the three spatial coordinates of the N particles. But the only way we could accomplish the suggested partition into triplets is to *already* know that the configuration can be divided as such, and that amounts to assigning to the word "configuration" what we think it means: collection of positions of particles. And this amounts to saying that there *are* particles in three–dimensional space, implicitly adding them to the furniture of the universe, something that we have explicitly denied from the start. In short, if one wants to insist that the world is "made of"[2] wave functions, she needs to specify some rule or map from the M-dimensional space to three–dimensional space.

Connected to this problem, we should also explain why the world is *as*

[2]For simplicity, here and in the following I might use the locution "is made of" as short for: "is mathematically represented by".

if there are (macroscopic) three–dimensional objects that move around in three–dimensional space. We think that macroscopic objects have properties, among which to be located in some position in three–dimensional space, or to have a given temperature, and so on. A fundamental physical theory should be able to describe, at least in principle, the behavior and the motion of these objects together with their properties, in one way or another. In orthodox quantum mechanics there is a rule called the *eigenstate–eigenvalue rule* (EER) that is used to talk about properties in connection with the wave function: "an observable (i.e. any genuine physical property) has a well defined value for a system S when and only when S's quantum state is an eigenstate of that observable". In GRW the evolution for the wave function is constructed by modifying the Schrödinger equation to get rid of macroscopic superpositions. As a consequence, the wave function of a macroscopic object "collapses" very rapidly into one of the terms of the superposition but, because of the properties of the stochastic equation, it has tails that are never exactly zero. Since such a wave function is not an eigenstate of any operator that is supposed to represent properties, we cannot use the usual EER in GRW to determine the properties of macroscopic objects. So again, bare monism fails, leaving macroscopic objects with indefinite properties.

3 Dressed-up Monism

Albert realizes these failures, and supplements GRW with certain rules to solve the problems just seen. He first proposes [Albert 1996] that the Hamiltonian provides the required map to get three–dimensional space from configuration space. Suppose that physical space is $\mathbb{R}^M$, where *it happens* to be the case that $M = 3N$. The total Hamiltonian of the world is something like the following: $H = \nabla_q^2 + V(q)$, where $q \in \mathbb{R}^M$. Without any further restrictions, this Hamiltonian could apply to a space of any dimension M. But, Albert claims, it is an *empirical* fact of the world that the potentials V should be written as $V(q) = \sum_{i<j} V(|q_i - q_j|)$, where $q = (q_1, ..., q_N)$, $q_i \in \mathbb{R}^3$, for any $i = 1, ..., N$. And this is what *ensures* us of the appearances of the world as three–dimensional. The structure of the actual Hamiltonian, Albert says, is what explains why we *think we live* in a three–dimensional space, and there is no further explanation of why the Hamiltonian is the way it is, or the dimensionality M of physical space is what it is (for example, there is no explanation of why M cannot be any number but must be a multiple of 3.

In particular, there is no further explanation of why M cannot be a prime number[3]).

To solve the problem of indefinite properties, Albert and Loewer propose to replace the EER rule with a different one. For the property of localization of a macroscopic object, they put forward the following proposal: "particle x is in region R" if and only if the proportion of the total square amplitude of x's wave function which is associated with points in R is greater than or equal to $1-p$", where the parameter p is a conventional matter [Albert *et al.* 1996]. It is a supervenience rule, since it is a rule that explains how our talk about macroscopic objects and properties (the macroscopic talk) supervene on the talk in terms of wave function (the microscopic talk). In this way, they say, it is possible to recover what we usually mean when we talk about localizable objects on the macroscopic level and the appearances of those objects to be localized while they are not.

Note that here neither of the rules implies any additional ontology in any way. Rather, they are just practical rules that should be added for our epistemic purposes.

4 GRW with a Primitive Ontology

In this section I would like to present a couple of completely different approaches, in which some mathematical object *other than the wave function* is representing matter.

Upon reflection, the wave function, living in such an abstract space, does not seem to be the right kind of object to describe physical objects. Rather, given that matter appears to live in three–dimensional space and to evolve in time, the obvious choice to represent it seems to be a mathematical object in three–dimensional space, or in space-time! Such mathematical object has been called the *primitive ontology* of the theory[4]. By definition, given that it lives in configuration space and not in three–dimensional space, the wave function is not a possible primitive ontology. For this reason, Albert's formulation of GRW could be called "GRW0", since it does not have any

[3] This has been suggested by Tim Maudlin [Maudlin p.c.].

[4] See for example [Goldstein 1998], [Dürr *et al.* 1997], [Goldstein *et al.* unpublished], [Allori *et al.* 2008], [Tumulka 2006a], [Allori *et al.* 2005] [Ghirardi 2007], [Allori 2007] and references therein.

primitive ontology[5].

John Stuart Bell expressed a similar idea in his [Bell 1987], and proposed a "version" of GRW with a primitive ontology. Consider the space-time points (x_i, t_i) in which the wave function collapses. One could call these events "flashes"[6]. Bell's proposal is to take these events as the primitive ontology of the theory. For this reason, it seems appropriate to call this reformulation of GRW "GRWf"[7]. The flashes happen randomly with a given temporal frequency and their probability is determined (quantitatively) by the wave function. In particular, once a particular history of the wave function has been chosen in a given time interval, the set of the localization events in space-time in such interval is determined[8].

Gian Carlo Ghirardi – the 'G' in GRW – has proposed another GRW theory with as primitive ontology the scalar field $M^\Psi = M^\Psi(x,t)$ on three–dimensional space, determined by the wave function [Bassi *et al.* 2003]. Since the primitive ontology of this theory is the mass density field, this theory is called "GRWm".

Let me emphasize how all the quantum theories just described and other fundamental physical theories are theories about the temporal evolution of a primitive ontology. For example, in Newtonian mechanics the primitive ontology is given by point-particles, whose time evolution is determined by the Newton's law of motion and the laws of the force. A similar thing happens in Bohmian Mechanics: the primitive ontology is also given by particles, whose law of motion is determined by the wave function. GRWf and GRWm are theories with the same characteristics: in GRWm the primitive ontology is given by the mass density field, whose law of motion that is determined by the wave function. GRWf is directly formulated in a space-time, but one can tell the story of the world in terms of flashes in space-time. In both GRWf and GRWm the primitive ontology (flashes and mass density field, respectively) evolves according to an equation governed by the wave function that in turn evolves stochastically, while in Bohmian mechanics the wave function evolves deterministically according to Schrödinger's equation. This

[5] This name was introduced in [Allori *et al.* 2008].

[6] This name has been first suggested in [Tumulka 2006a]

[7] The names "GRWf" and (see later) "GRWm" were introduced in [Colin *et al.* 2006]. Other names has been proposed for GRWf, like for example "flash-GRW", "flashy-GRW" or "Bell-GRW".

[8] See [Bell 1987], [Tumulka 2006a], and [Allori *et al.* 2008] for technical details about GRWf.

suggests that there is the following common structure: in these theories there is always a primitive ontology that mathematically represents the microscopic constituents of macroscopic physical objects, and there are other variables (in the quantum case the wave function) whose role in the theory is to implement the dynamics for the primitive ontology. The specification of the primitive ontology and of these dynamical variables completely determines the theory[9].

5 Objections to GRW with a Primitive Ontology

Let me now present possible problems for GRWf and GRWm. and possible ways to respond them.

The first charge is that GRWf and GRWm have the problem of explaining what the wave function is: if physical objects are described by the primitive ontology, the wave function has to be something else. But what? The discussion above about the common structure between fundamental physical theories can help us answer this question. The wave function, in all theories analyzed, has a common role: while the primitive ontology specifies what physical objects are, the wave function specifies how physical objects move. For this reason, Detlef Dürr, Shelly Goldstein and Nino Zanghì [Dürr *et al.* 1997] have proposed that the wave function should be intended as a physical law. Objections have been raised to this view, especially by Harvey Brown and David Wallace [Brown *et al.* 2005]. First of all, laws are time independent, while the wave function evolves in time. Dürr, Goldstein and Zanghì [Dürr *et al.* 1997] and more recently Shelly Goldstein and Stefan Teufel [Goldstein *et al.* 2001] have anticipated and replied to this objection claiming that even if it might be difficult to accept the wave function as a law in the current theories, it will become straightforward once we reach a theory of quantum cosmology in which the wave function is static. Another objection to the view of the wave function as a law focuses on the fact that there seem to be multiple degrees of reality: there are material entities, the primitive ontology, and there are nomological entities, the wave function. One could avoid the problem endorsing a nominalist point of view for laws. As

[9]For more on this, and for a more comprehensive (but not exhaustive) list of all the possible combinations of primitive ontologies, dynamical variables and evolution equations, see [Allori *et al.* 2008], [Allori 2007].

an alternative, one could maintain that laws exist as abstract entities. One could insist in fact that, even if the view has problems, they are not strong enough to make one abandon the view altogether. This, of course, needs to be argued, and indeed it has[10]. Another possible option is to try to eliminate the wave function completely from the theory, as it has been attempted by Fay Dowker and collaborators [Dowker *et al.* 2004], [Dowker *et al.* 2004], [Dowker *et al.* 2005], that have developed some toy models of quantum mechanics without using the wave function at all.

Another charge against GRWf and GRWm is that they are artificial: there is just one equation in GRW, and it is about the wave function. What else could describe physical systems? I think this objection is question begging: the whole point is to establish whether in GRW there is only one evolution equation or not, and if not, which one is fundamental. GRW0 assumes there is just one equation, while GRWf and GRWm explicitly *deny* that. And one cannot assume as a premise something that is supposed to be established.

Another objection to GRWf and GRWm could be that these theories add the primitive ontology even though it is of no use: everything can be done without it. Again, the argument is question begging: the very issue is to determine whether it is possible to derive everything with the wave function only. I am about to argue that the situation is not as described, so if I am correct, this argument fails.

If it is not true that GRW0 is the most natural interpretation, one could claim that it is the simplest in the sense that it postulates the existence of just one thing, the wave function. In contrast, GRWf and GRWm postulate also the existence of the primitive ontology. So, appealing to Occam's razor, GRW0 should be preferred. First of all, I think that this formulation of the objection is misleading: also in GRWf and GRWm there is just the primitive ontology in the *physical* world! Be that as it may, this is not a very compelling argument, I think. In fact, the strength of this argument clearly depends on whether one accepts Occam's razor or not. One could argue, *contra* Occam, that theory should be chosen on the basis of its explanatory power, that is not necessary connected to its simplicity. One could therefore claim that GRWf and GRWm are more explanatory or explain things better than GRW0. In the next section we will see the amount of work GRW0 has to, here let me focus on GRWf and GRWm. Both GRWf and GRWm are in line with the traditional realistic interpretation of classical mechanics: there

[10]See [Maudlin 2007b] for a recent realist proposal about laws of nature.

are microscopic entities in three–dimensional space, evolving in time. We do not have to explain the *appearance* of three–dimensionality, since the world *is* three–dimensional. Concerning macroscopic properties, there seem to be no problems, since in principle we are in the same situation we were in the classical framework. Arguably, in classical mechanics one can identify macroscopic properties more or less naturally given by how the fundamental objects can clump together to form more complex bodies interacting in a variety of ways. For example, suppose I want to account for the fact that a comet is an object that has a given localization at a given time. In classical mechanics I can do that in terms of the microscopic components of the comet and their interaction with each other: there are such-and-such atoms that form such-and-such compounds, that interact *via* such-and-such chemical bonding to form a solid object whose motion (and therefore its localization at different temporal instants) can be just as effectively described by the motion of its center of mass. Similarly, a property like liquidity can be explained in terms of the chemical bonding between the microscopic constituents, while transparency can be explained in terms of the optical properties of the compound. Also in GRWm and GRWf we start from a primitive ontology in space or space-time. Therefore, also in these theories we should be able to recover (at least in principle) all macroscopic properties of physical objects (temperature of a gas, ductility of a metal, elasticity of material, transparency of glass, and so on) with a transparent mathematical method. More generally, this should be done for any theory with a primitive ontology[11]. An antireductionis could object all this, but the point here is that in GRWf and GRWm we are not in any way worse off than in classical mechanics. That is, whatever can be said against reductionism in classical mechanics, in principle can be said for GRWf and GRWm. But there seem to be no *additional* problem for reductionism in these theories due just to the fact that they are quantum theories.

6 Objections to Dressed-up Monism

The main problem is that GRW0 is incredibly radical in an unnecessary way: if less far-fetched alternatives work, why go radical? Even if we grant that

[11]Indeed, it has been done in the framework of Bohm's theory in [Dürr *et al.* 2004] and in [Allori 2002]. In the GRW framework, more work needs to be done. In any case, see [Bassi *et al.* 2003] and [Goldstein *et al.* unpublished] for some related comments on the matter.

there are reasons to go that way, still the does not seem to provide a good "mechanism of explanation". And even if we set this issues aside, there are worries about whether the monistic research program can ever get off the ground.

The pictures of the world provided by GRWf and GRWm are, more or less, not too revisionary: there is space-time and there are histories of the primitive ontology in it. By contrast, the picture of the world given by GRW0 is at best extremely bizarre: physical space is a highly dimensional space, and all there is is a material field in that space. All the complexity, all the variety, all the individuality, all the multiplicity of things is in that object: planets, stars, tables, chairs, apples, trees, cat, reptiles, electrons, quarks, humans, aliens, me, you, Mother Theresa, George Bush, are not made of particles, are not made of fields in three–dimensional space, rather they are "all there together" somewhere meshed in the wave function. As also pointed out by Bradley Monton[Monton 2002], GRW0 is even more radical than the brain-in-a-vat scenario: at least in that case brains are in space-time, while in this view there are basically no brains at all, since there are no individuals at all! GRW0 seems far too revisionary than needed: it is *possible* that the world is as described but there seem to be no reason to believe it is the case. In fact, it seems we can do perfectly fine without GRW0: as we discussed, nothing is deeply wrong with the alternative view that the world *is* actually three–dimensional with three–dimensional objects moving around. As a matter of methodology, I think that we should not opt for some radical view if there are no strong reasons to reject less revisionary perspectives.

At any rate, this is not an argument that prevents in principle the monist to find the rules she needs. Indeed, Albert has proposed his own rules, as we have seen. Concerning his first proposal, arguments against the possibility for the Hamiltonian to provide the correct rule of correspondence are given in [Monton 2002]. I do not wish to focus on those arguments in this paper: even if Albert's argument is sound and the Hamiltonian could in principle be enough to define a suitable rule, I still find the argument unconvincing. In fact, let us grant Albert that the Hamiltonian is indeed enough to explain why it seems to us that we are living in a three-dimensional world even if we are not. What are the reasons for which the Hamiltonian is the way we write it? It seems straightforward to me that the reason we *use* in physics books a certain Hamiltonian, and not some other, is that we *already assume* that we are in three–dimensional space, and not the other way round. That is, we do not deduce the three–dimensionality of space from the fact that in the physics book we find a particular kind of Hamiltonian. Therefore, it seems that the explanatory structure in Albert's view is upside down: is it the structure of the Hamiltonian that explains the appearance of the three–dimensional world, or the existence of such a world that explains the structure of the Hamiltonian?

There seems nothing to say about the effectiveness of proposed supervenience rule: it works. It allows us to define a clear rule of correspondence between the microscopic language (in term of wave functions) and the macroscopic everyday language (in terms of macroscopic properties). But notice that not only do we need to explain the appearances of three–dimensionality and localizability, but also of *all the other* macroscopic properties. That is, not only do we need to supplement the theory with the Hamiltonian rule for three–dimensionality and the supervenience rule for localization: we also need other rules to account for *every* single property we think a macroscopic object (including "us") can have! For example, not only is it the case that my cup of coffee is localized on my table, but also my cup of coffee *is* a cup of coffee – it has a particular shape. Also, as a matter of fact, my cup of coffee is white, and it is fragile. In addition, not only am I localized in my office in front of my computer and close to my cup of coffee, but also I have the property of thinking certain thoughts. So GRW0 should be able to account for all these properties, and many many more. The idea is to do so introducing supervenience rules. For example: "An object is a cup of coffee iff the wave function is localized in a cup-shaped region of three–dimensional space." To account for the color of an object, the situation is more complicated since it requires us to talk about the light deflected by the object. But both the object and the light are part of the wave function, so one needs to find a way to accommodate this. The same situation (or maybe a more complex one) arises for fragility, since it involves what would happen to the object under certain circumstances. Not to mention the task of accounting for mental properties (see later).

Therefore, at the end of the day it seems that GRW0 is more like a research program rather than a fully developed account. There is of course nothing particularly wrong with that, but it should be remembered that it was maintained that GRW0 is simpler than the alternatives since it involves just the wave function. Is it really so with all these rules?

Be that as it may, here is another concern: there is no deep justification for the additional rules. In fact, the answer to the question "Why these rules?" is nothing but "Because they work ". The problem is therefore that the GRW0 account of macroscopic properties does not seem to provide a genuine account of these properties at all. Let us contrast this with the situation in GRWf and GRWm. As anticipated, in the framework of theories with a primitive ontology we can explain macroscopic properties starting off from three–dimensionality and compositionality (there is microscopic stuff in space that evolves in time, and the macroscopic objects are composed of this microscopic stuff): we have a clear "mechanism of explanation". This is not so in GRW0, in which one has to derive macroscopic properties without three–dimensionality, without compositionality, without anything, just using plenty of *ad hoc* rules.

To conclude, let us even grant Albert that his rules are plausible and successful. I think that there is a deeper and bigger problem. In theories with a primitive ontology, there seem to be no mystery about the fact that there are individuals among the three–dimensional objects: they just seem particular clusters of primitive ontologies. The only mystery there is (if any, depending of what position one takes with respect to the mind-body problem) is that (some of?) these individuals have conscious experiences. Of course, if there is a problem here, there is a problem for every physical theory, starting from classical mechanics. It is worth noting, though, that theories with a primitive ontology do not need to solve the mind–body problem in order to account for what (physically) happens in the world around us: they simply leave it out from the beginning, claiming that all physics does is to account for the behavior of *material* objects. In the case of GRW0 instead, since physics ought to explain the *appearances that we have*, and since there are (fundamentally) no individuals and no individual perceptions, the mind-body problem is right in from the beginning and cannot be left out from the discussion. Suppose I want to account for my seeing the motion of a projectile in a gravitational field. In classical mechanics this is equivalent to the request of accounting for the motion of a projectile in a gravitational field. There is no need to invoke my visual perception of the projectile. The evidence (i.e. the motion of the projectile) is stated in the language of physical facts, and not in the language of experience. The same can be said in the case of GRWf and GRWm. In GRW0, instead, one has to stick with the original request and has to account for *my perception* of the motion of the projectile *to start with*. Since in GRW0 there are no individual perceptions, we need to account for the fact that it seems that there are such perceptions. But this amounts to have solved the mind-body problem, which nobody has a clear idea of how to do! If we don't have a primitive ontology, the connection between physics and the behavior of ordinary objects has to be made at the level of experiences. So one cannot avoid to discuss about how conscious experiences come about. In other words, whether one considers the gap between the physical and the mental in principle unsolvable by physics or not, this issue has no implication for GRWf and GRWm, while this is not the case for GRW0. Therefore, while GRWf and GRW are independent to the mind-body problem, the success of GRW0 crucially depends on its solution: if it cannot be resolved by physics the research program *cannot even start*. This is a good reason for which it seems more sensible to choose right from the beginning an ontology in three–dimensional space - that does not require any mentioning of the mind-body problem - instead of having an ontology in some abstract space and then find ourselves dealing with the mind-body problem right from the beginning. To put it differently and to sum up, there are two problems we have to face when we want to describe the world around us: an "easy" one and a "difficult" one. The easy one is to explain the behavior of macroscopic objects in three–dimensional space in term of the motion of microscopic objects in three–dimensional space. The difficult one is, in the GRW0 framework, to explain perceptions, as for example physical space as it appears to us as being $\mathbb{R}^3$, while it is actually $\mathbb{R}^M$. In the approach in terms of primitive ontology the difficult problem is left to a future theory (of consciousness or a more complex physics depending on what one's view is), while physics is concerned only about the easy one: once we have left perceptions out, we can dedicate physics to the description and the explanation of the motion of bodies in three–dimensional space. On Albert's approach, in contrast, we are *required* to explain perceptions in order to begin explaining everything else. Physics and the theory of perception are completely merged and therefore everything becomes more difficult, if not impossible, at any level. Notice that what is claimed here is not that we should not aim at such a complete theory. But since it happens that we can do physics without having to have a theory of consciousness, why not do that?

7 Conclusion

As a conclusion, I believe that GRW in particular and any fundamental physical theory in general should not be interpreted as a theory about the time evolution of the wave function, but rather as the time evolution of a primitive ontology in three–dimensional space. This is a much more desirable approach than others in the spirit of recovering our perception from the behavior of an entity in some abstract space. In fact such a project is is doomed to failure if physicalism is false, while it has not been done yet and has been argued to be very difficult to obtain assuming the mind-body problem can be solved in physics[12].

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[12]For completeness, I should add that, in addition to the authors already mentioned, positions contrary to mine defending wave function monism that I did not discuss are entertained also by Peter Lewis [P. Lewis 2005], and by Harvey Brown and David Wallace [Brown *et al.* 2005], while one can find ideas similar to those expressed in this paper in [Monton 2002], [Allori *et al.* 2008], [Goldstein 1998], [Allori 2007] and [Maudlin 2007a].

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