Entension,
or
How it could happen that an object is wholly located in each of many places.

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1 Introduction

"Entension" is my name for the phenomenon of a material object being wholly located in multiple places.[1]

Normally this is not how we think material objects work. I, for example, am a material object that is located in multiple places: this place to my left where my left arm is, and this, distinct, place to my right, where my right arm is. But I am only partially located in each place. My left arm is a part of me that fills exactly the place to my left, and my right arm is a distinct part of me that fills exactly the place to my right. I am located in multiple places by virtue of having distinct parts in those places. So entension is not happening to me — I do not *entend*.

When an object fills up space the way I do, by being partly located in multiple places, I say that it *pertends*. When an object is located in multiple places, whether wholly or partially, it *extends*.

This terminology is intended to ring some bells, at least for those readers who've followed the literature on identity over time. In that literature, it's commonplace to distinguish between 'endurance' and 'perdurance'. An *enduring* object is located wholly at each of the times at which it exists; a *perduring* object is located partly at each of the times at which it exists; and any object that is located at more than one time (regardless of whether it endures or perdures)

[1] Friends of entension include John Bigelow (1995, pp. 21–27), Ned Markosian (1998), Fraser MacBride (1998, pp. 220–227), Peter van Inwagen (1981), and, according to van Inwagen, Aristotle (van Inwagen 1990, p. 98). There are few, if any, enemies of entension in print, perhaps because they believe that entension is self-evidently absurd (though I hope this paper will do something to counter that attitude). Van Inwagen mentions Roderick Chisholm and David Lewis as his stalking horses (van Inwagen 1981, p. 129,131) though neither of those philosophers has attacked entension directly in print.

persists. (Johnston 1987) Entension, then, is the spatial version of endurance, "pertension" being analogous to "perdurance", and "extension", the neutral term, analogous to "persistence".

In this paper, I aim to do two things. First, I want to convince you that there's nothing conceptually shady about entension — that it's conceptually possible (section 2). In my view, we can't discover whether anything entends just by reflecting on the matter. Nor is it possible to discover whether anything entends just by inspecting superficial features of the world (section 2.3) But that's not to say that we should just throw up our hands and be sceptics — I am a naturalistic metaphysician, and I think we should try to read these things off from science, if possible. I discuss what it would take for us to have scientific evidence of entension (section 2.4). And, in the second part of the paper, I give a more detailed argument that we can extract such evidence from contemporary physics (section 3).

2 Monism

The most extreme version of a doctrine of entension was offered by Spinoza. According to him, nothing can be extended, except by being entended; and so, there is only one extended thing, the universe (which he identifies with God).[2] I will call this doctrine "monism". (Thus defined, monism is to contrasted not with dualism, but with pluralism). And for convenient reference, I'll call the universe, conceived of so that so that monism is true, "the Absolute".

This is a good test case. While I don't think Spinoza was right (and I don't agree with his arguments that pertension is impossible — but that is another story), it's instructive to see whether his hypothesis that there is only one material thing filling all of space can be resisted on a priori grounds. I don't think it can be — from which it follows, I think, that there's no a priori argument that entension is impossible.

I should explain how monism is committed to entension. Spinoza believed in monism partly because be thought pertension was impossible; but setting his reasoning aside, any monist must believe in entension, if she is to believe in spatial extension at all. According to monism, the Absolute is supposed to be just as extended as we think that the universe is. But it cannot be pertended — it cannot fill space by having spatial parts — because according to monism, there is nothing distinct from the Absolute to be its parts.

There's a debate among Spinoza scholars about the status of ordinary objects like chairs, tables, and human beings. Spinoza says that these things are "modes", or as we would say, properties, of the universe. The debate concerns whether he can have really meant this. Did he really mean to say that I stand to the Absolute as redness stands to a tomato? Or did he just mean that I am a mere dependent existence (just as modes were supposed to be)? Both of these options seem unsatisfactory to me — the first because it's barely intelligible, the second because it's too deflationary — so I want to suggest an alternative that I'm prepared to defend the possibility of. I make no claim at all about whether this view is compatible with Spinoza's text.

[2] See, for example part 1 propositions 12 and 15 of the *Ethics* (Spinoza 1994), or, for a discussion, Bennett (1984, ch. 4).

My suggestion is that the monist can grant that we are right to believe that the things we take to be chairs, tables, or ourselves exist; but we are mistaken in supposing that these things are numerically distinct. Ordinary objects all exist (in Spinozistic language, they are all substances) but, if monism is right, they are all identical. According to monism, the chair in my office, and the desk in yours are like the morning star and the evening star — you can't tell just from thinking about them that they are identical, but as it turns out they are. (For further discussion of this point, see section 2.2).

This raises an important question. If all things we take to be desks and chairs and humans beings and so on are identical, are there any desks or chairs or human beings? I cannot give this question a blanket answer, because the answer depends on the correct conceptual analysis[3] of "desk", "chair", and so on. Perhaps all it is to be a chair is to be typically sat on. In that case, there may well be a chair, for indeed I typically sit on the thing that's in my office. If the meaning of "chair" allows that one and the same thing can be a chair, and a desk, and a human being, and a universe, and can sit on itself, then, by golly, there are chairs. On the other and, perhaps it's part of the meaning of "human being" that a human being cannot be a poached egg. In that case, contrary to what we might have thought, there are either no human beings, or no poached eggs.

It seems likely that the monist will be unable to avoid revisionary claims. But that's OK — monism is an outrageously revisionary metaphysical claim, and I don't endorse it. What I'm going to do is to use it as an example to illustrate some attempts to show that entension is impossible, and to explain why I think those attempts fail (sections 2.1–2.3). Lest this appear to be idle sophistry, I'll also discuss (briefly) how it is that we know that monism is false (section 2.4).

2.1 Objection 1: Entirely versus wholly located

> **Objection 1:** How can it be that an object is wholly located at one place when that is not the only place where it is located? Suppose that the Absolute is a chair in my office, and a desk in yours; or at least, there's a chair shaped region of space in my office occupied by the Absolute, and a desk shaped region of space in your office occupied by the Absolute. Well, isn't it just false, that the Absolute is wholly located in my office — there's some more of it elsewhere (namely, in your office)

This objection trades on an ambiguity of quantification. We need to distinguish between an object being *wholly* located at some place r and that object being *entirely* located at some place r. An object is entirely located at r when there is nowhere else that it is located; by contrast, an object is wholly located at r when it has no parts missing — no parts not located at r.

In the example above, it is true that the Absolute is not entirely in my office (because it is also in yours). There's somewhere not in my office where the Absolute is. But there's not any part of

[3] I mean conceptual analysis in a broad sense: it might include empirical investigations into the real essences of natural kinds.

the Absolute that's missing from my office. It doesn't follow from the fact that the Absolute is not *entirely* in my office, that it is not *wholly* in my office.

Here are some semi-formal definitions of wholly and entirely located that will work in both the spatial and temporal cases:

Definition of 'entirely located': x is entirely located at r iff x is located at r and there is no region of space-time disjoint (i.e. not sharing a subregion) from r at which x is located.

Definition of 'wholly located': x is wholly located at r iff x is located at r and there is no proper part of x (i.e. a part of x not identical to x) not located at r.

The term 'located" also lends itself to some ambiguity. In my usage, an object is located at r iff it is located at all of r's subregions. In this usage of "located" all and only extended objects are multiply located. Some people might want to use "located" to mean what I would call "entirely located". If you use located that way, then nothing is multiply located — but that's not what is meant by "located" in this debate — it's supposed to be agreed by all parties that extended objects are multiply located.

Notice, by the way, that even a pertended object is wholly located in the place where it is entirely located. What is distinctive of entension is that an entended object is wholly located in places other than those at which it is entirely located — or, equivalently, that it is wholly located at more than one place.

2.2 Objection 2: Conceptual parts

> **Objection 2:** I can understand what it would be for monism to be true if what it is saying is that all of the parts of the universe are inseparable from each other. But that's not to say the parts don't exist. It suffices for an object to have proper parts that we be able to conceive of those parts separately, even if the parts themselves are inseparable.

This sort of objection comes along with a distinction that is supposed to make the objection sound more plausible. One might distinguish between on the one hand, the conceptual parts of an object (those being the ones for whose existence it suffices that we be able to conceive of them separately), and on the other hand, the physical parts of an object (those being the ones that satisfy some extra condition such as being separable).

For example, Denis Robinson appeals to this move to defend the existence of arbitrary temporal parts of objects:

> [T]he use I propose of this notion [part-whole] requires moving from the idea of physical to the idea of purely conceptual partition. But common sense finds no difficulty with... this shift (as when we advance from talk of 'the parts of the watch' to 'the part of Africa north of the equator'). (Robinson 1982, p. 322)

I am uncomfortable with this, because I can think of no way of drawing the distinction between conceptual and physical parts that would not trivialise entension. Consider, for example, drawing the distinction in terms of separability: metaphysical parts are separable parts. That would mean that monism reduces to the claim that everything is inseparable from everything else. But that was not what was intended at all. The idea is supposed to be that there is only one thing, not that everything is held together by super-glue.

It seems to me that the distinction between conceptual and physical parts begs the question against entension. But not everyone who believes in entension agrees. Ned Markosian is a believer in entension who accepts Robinson's distinction. He imagines a perfectly homogeneous entended sphere. For all that this object has no proper parts, he thinks, there's some sense in which "If any object has some extension then it has two halves" is obviously true, and this leads him to say "it is apparent that anything with some extension will have *conceptual parts*, even if it doesn't have *metaphysical parts*." (Markosian 1998, p. 224) Markosian would presumably want to define "entension" in such a way that it didn't conflict with this doctrine.

But why should we think that there *are* such halves? The reasoning must go something like this: suppose we had here a homogeneous entended sphere like the one Markosian imagines. I could intelligibly say or believe things about the left half of the sphere without saying or believing them about the right (and vice versa). For example, I could intelligibly say "I am looking at the left half of the sphere and not at the right half". So it seems to follow that the left half is distinct from the right because I can have attitudes to the one and not the other. Only this sort of argument would furnish the requisite connection between objects' having parts and our abilities to conceive separately of those parts. Only this sort of argument would make conceptual parts really *conceptual*.

This argument can't be valid, though, because there are logically analogous arguments with true premises and false conclusions. I can intelligibly say "I am looking at the morning star and not at the evening star" — but this doesn't show that the morning star and evening star are not identical, or that they must be distinct parts (temporal parts perhaps) of Venus. True identity statements must, perhaps, be necessary, but it shouldn't follow that they are knowable apriori, let alone that their denials must be obviously absurd.

There is a problem, of course, about how to give an account of the meaning of the noun phrases "the morning star" and "the evening star" (and, to make matters harder, the proper names "Phosphorus" and "Hesperus") in a way that's compatible with these arguments being invalid. But no-one should doubt that the arguments are invalid.

Rather than stake out a position on the semantics of singular terms and identity statements, let's bracket the issue by saying that the morning star and the evening star are "a posteriori identical". I think a precisely analogous thing is going on in the case of Markosian's sphere. If the sphere entends, then its left and right halves are a posteriori identical. In the case of monism, a posteriori identity is ubiquitous. Once we think of the "halves" of entended objects in this way, the need for "conceptual parts" evaporates.

2.3 Objection 3: Change and homogeneity

> **Objection 3:** Let's admit entension is possible. We know very well however, that nothing entends, and that monism is false, because any entended objects would have to be perfectly homogeneous. If there were a non-homogeneous entended object, then there would have to be regions inside such an object, portions of it, conceptual parts of it, or whatever, that differed in intrinsic character. Now you can't say that these parts are a posteriori identical, because would violate the indiscernibility of identicals.

To see an example of this problem, think about my chair and your desk. The monist says that those things that seem to be parts of the universe (such as our furniture) are really identical to it. But that, runs the objection, is conceptually impossible, because my chair is lighter than your desk, while nothing can be lighter than itself.

For another example, consider a revised version of Markosian's sphere. Suppose that, instead of being perfectly homogeneous, the sphere's left half is red, and its right half is blue. Now we would have a reason for distinguishing these halves that does not depend on any assumption that true identity statements must be obviously true. Nothing can be both red and blue — so there is a reason for thinking that the sphere has two distinct parts after all.

One thing we could do about this problem is to admit defeat. The objector here admits the conceptual possibility of entension (or has nothing to say against it at least) — she just denies the possibility of entended non-homogeneous objects. This is a possible and interesting middle ground. However, I will be needing entended non-homogeneous objects later on in the application of all this to quantum mechanics, so I cannot take that option.

So how should we solve the problem? Let's begin by observing that it is strictly analogous to a problem that's raised in the temporal case, a problem about endurance.

In the case of endurance, the puzzle is about the temporal analogue of non-homogeneity, which is change. Suppose a poker begins its life hot, at t_1, then cools down over time to become cold at t_2, at which point it is destroyed. The poker endures, so that it is wholly located at both t_1 and t_2. So the hot thing at t_1 is strictly identical to the cold thing at t_2. But that's impossible — nothing can be both hot and cold.[4]

There are a number of stock answers to this problem. I will give a quick outline of the one that I prefer, which involves temporally indexed properties. Objects that change their temperature are not hot or cold *simpliciter*. They are hot at some times and not at others. The poker is hot at t_1 and cold at t_2, and there's nothing contradictory about that. Actually, I'm not sure what it means for an object to be hot or cold *simpliciter*. Perhaps it means that the object is hot (or cold) "all over" — hot (or cold) at every region of space-time at which it is located. But no-one who thinks that pokers are four-dimensional objects — that pokers are multiply located in time, that is — should think that the poker of our example has that property. To set up the case, you need to stipulate that the poker is cold at some times and hot at others.

[4] For a recent statement of this type of argument, see (Sider 2001, pp. 92–98).

The objector should not be satisfied yet. Temporally indexed properties are suspicious characters: can they be compatible with properties that are not time-indexed? Is being hot at t_1 a matter of bearing a certain relation to t_1? If so, does that make heat a relation and not a property? To answer these questions it would be good to have a reduction of indexed properties into properties *simpliciter*. Fortunately, I have such a reduction: The poker's being hot at t_1 is a matter of the poker's heat distribution, which is a property that the poker does have *simpliciter*. Some possible heat distributions are such that an object beginning at t_1 and having that heat distribution must be hot at t_1. Other heat distributions are such that an object ending at t_2 and having that heat distribution must be hot at t_2. The heat distribution of the poker falls into the former class, but not the latter. That the poker has the heat distribution it does explains its being hot at some times and not others. Heat distributions are intrinsic, non-relational properties, which heads off objections about heat turning out to be extrinsic or relational according to the indexed properties account of change. (Parsons 2000, pp. 409–411)

Think of this proposal in Quinean terms, as a trade-of between ontology and ideology. We can either have an enlarged ontology of temporal parts, and a theory that speaks in such familiar terms as "hot" and "cold". Or, we can have an ontology without temporal parts, at the cost of a more complicated theory that does everything in terms of heat distributions.

The same approach will work in the spatial case. Call the left half of the region of space occupied by the red and blue sphere s_1, and the right half of that region s_2. The sphere is red at s_1 and blue at s_2. As I put it, the sphere has no particular colour, but a colour distribution which assigns red to s_1 and blue to s_2. If the "halves" of the sphere are identical to it, then they have all these properties too. If the sphere entends, then it's just false that the left half is red (where "red" means "red all over") and the the right half is blue (where "blue" is treated in the same way), so the problem does not arise.

Take the case of the desk, the chair, and the Absolute. Call the chair-filled region in my office s_3, and the desk-filled region in your office s_4. The Absolute has no particular mass, but a mass distribution that assigns particular quantities in kilogrammes to the regions s_3 and s_4 and their subregions. The thing I sit on in my office (which is none other than the Absolute) is more massive at s_4 than it is at s_3, in just the same way that a hammer is more massive at its head than at its handle. But it does not follow that the Absolute is more massive than itself, any more than that the hammer is more massive than itself.

2.4 How we know that there are many things

It might be thought that I've now defended entension all too well. If all I've said is true, then why suppose that monism is false? Even granting that it is false, how do we know that it is false? How could we know in any case of any extended object whether it is entended or pertended?

It seems to me that monism is a kind of sceptical scenario, in that it can be concocted in such a way as to produce the same evidence as any rival pluralistic hypothesis. In part, my discussion of homogeneity was an illustration of this. This, however, is no new problem, but simply an instance of the under-determination of theory by data. The evidence available to us hardly ever suffices to conclusively falsify theories in natural science, let alone metaphysics.

Different theories that are each perfectly empirically adequate can however be theoretically virtuous to different degrees. For example, Kepler's astronomy had the same observable consequences as the theories that had preceded it. If we restrict our evidence to the apparent motion of the planets — which was what was relevant at the time — our choice of Kepler, Copernicus, or Ptolemy is under-determined by the available data. Nonetheless, Kepler alone was able to eliminate epicycles from the orbits of the planets. (Hull 1959, pp. 128–137) His theory was strikingly simpler and more elegant than its rivals, which is a good reason for believing it, at least in the context of under-determination.[5]

Similar things will happen with monism. If we try to transform all of the things we know about the world, and natural science in particular, to make it compatible with monism, we end up with a theory that is strikingly more complicated than what we would ordinarily believe. Think, for example, of what happens when two billiard balls collide — a cue ball hitting a stationary ball, say. There are various explanations we can give of what happens, using classical mechanics, supposing that the collision is close enough to being elastic: each ball has a kinetic energy associated with it, which can be transferred between the balls but not created or destroyed. The conservation of energy explains how the balls behave.

To transform this explanation into terms compatible with absolute monism, we would have to speak in terms of energy distributions instead of quantities of energy. To replace the conservation principle we would need a seemingly ad hoc rule that states the ways in which the energy distribution of the Absolute can evolve over time.[6] It's for this type of reason that I think monism, or indeed any hypothesis according to which macroscopic scattered objects entend is implausible. Things are, however, quite different at the microscopic level, for reasons I will now discuss.

3 Entension and QM

Quantum mechanics has at least one thing in common with Spinozistic monism. Analytic philosophers tend to think that both are hard to understand as pieces of serious metaphysics.

[5]This is an example of weak under-determination, where the empirical adequacy of two theories gives us no reason to choose between them. It is also possible that theories may be strongly under-determined — that neither empirical adequacy, nor any other theoretical virtue gives us reason to choose between them. My claim is that monism is weakly, but not strongly, under-determined by the available data. (Thanks to Agustín Rayo for pointing out this distinction to me).

[6]Ways of formulating classical dynamics that are compatible with monism have been developed by physicists. Hamilton's equations of motion are an example: they describe the evolution of the universe over time as a trajectory through "phase space", which is a many-dimensional space, each of the points of which corresponds to a possible state of an entire Newtonian universe. (Torretti 1999, pp. 92–94) Hamilton's equations are strikingly elegant and would provide the type of rule that would be needed to *state* classical dynamics against a monist background. However, the pluralist has a further explanation of why Hamilton's equations are true — namely that they can be derived from the normal principles of classical dynamics, with their familiar ontologies of individual objects having particular masses and momenta.

In the case of QM, that's a bit of a problem if you are a naturalistic metaphysician.

What I want to do in this section is to sketch a way of thinking about quantum phenomena which at least makes sense as a piece of metaphysics. I can't claim that this is the only way to do it (if I could do that I would have solved an outstanding problem in the philosophy of physics!) but it seems to me that this is most attractive view currently on offer. To do that, I'll first describe what the puzzling quantum phenomena are, for which we need some kind of metaphysical explanation (section 3.1); then I'll describe the general strategy — the "interpretation of quantum mechanics" that I think best explains them (section 3.2). Then I'll argue that this explanation lends itself to the hypothesis that some things entend (section 3.3). And finally I'll address some objections and tie up some loose ends (sections 3.4–3.5).

3.1 Superposition

Consider the simple experimental setup shown in figure 1.

[DIAGRAM]

Figure 1: Half-silvered mirror

In this setup, a particle is emitted by the source at left, passes through the box in the center of the diagram, arrives at one or the other of the detectors, 1 and 2. The box deflects particles to the left half the time (as it were — we will see in a moment that this is not such a good description of what is going on). There are a number of ways of setting up such a experiment — one would be to have the particle be a photon, and the box contain a half-silvered mirror.

If you set up this experimental apparatus, what you would observe is half the particles being detected at detector 1 and half at detector 2. If you send just one particle through the apparatus, it will appear at detector 1 half the time, and at detector 2 the other half.

You might think that something chancy is happening at the mirror — particles are, as it were, flipping a coin to decide whether to pass through the mirror toward 1, or be reflected toward 2, passing along one or other of the dashed lines. But that is not the case, as can be determined experimentally, though not with the setup shown in figure 1. Suppose we arrange for our particle to pass through two of these boxes, as in figure 2.

[DIAGRAM]

Figure 2: Single particle interference

Here the particle passes through one box, and, whichever dashed line it follows, is reflected by the mirrors (represented by thick lines in the diagram) into the second box. Now, in this case, the particle will always come out at of the second box at the right, and arrive at Detector 3. If the boxes were simply deflecting randomly, and the particles were making up their minds which way to go *in the boxes*, you would expect the particles to arrive at Detector 3 only half the time, and at Detector 4 the other half. But this is not what happens — particles only ever arrive at Detector 3, never at Detector 4. If you shot the particles in from below the first box, then they would always arrive out at Detector 4.

This effect, which is called "single particle interference", is dependent on the paths shown by dashed lines both being open. If you block one of them with some wall that will absorb the particles, as shown in figure 3, then the effect disappears. Half the time you send a particle into this setup, it will simply be absorbed by the wall. 25% of the time, the particle will reach Detector 3; 25% of the time, the particle will reach Detector 4.

[DIAGRAM]

Figure 3: No interference effect with one path blocked

So, the only way to explain all these results is if the particle leaves the box in a superposition of states. The particle must travel along the paths represented by *both* the dashed lines in all of the figures so far.[7] Very promising for me, because the suggestion is that the particle is multiply located (we'll return to this point shortly).

3.2 The measurement problem

That makes for a bit of a problem. Consider figure 1 again. If each particle that goes into the box leaves along both dashed lines, why do we only observe it arrive at one detector? This is a famous conceptual problem for quantum mechanics: the measurement problem.

This is a problem of empirical adequacy. Without a saving hypothesis, the dynamical laws of quantum mechanics give us (seemingly) the wrong results. If you treat all that goes on at Detector 1 and Detector 2 as if it were just more of the quantum system, you'll get the result that both detectors end up in a superposition of detecting the particle and not detecting it. And if you treat the experimenter watching the detectors as just more of the quantum system, you'll get the result that the experimenter is in a superposition of believing that the particle was observed at Detector 1 and believing that the particle was observed at Detector 2.

It's hard to know what it would be like to be in such a belief state. But it ought to be very unlike being in the state of believing that the particle was observed at Detector 1 and *not* believing that the particle was observed at Detector 2, which is the sort of state that we appear to be in when we observe these experiments occurring.

[7]The claim that the superposed particle is located on both the dashed lines is not totally uncontroversial. What appears to be ruled out by single particle interference is the hypothesis that the particles are located on just one line. Some bold attempts have been made to explain these types of results while retaining that hypothesis: notably, David Bohm's contextual hidden variable theory (Albert 1992, pp. 134–179) (Barrett 1999, pp. 121–148) and Huw Price's "advanced action" (Price 1996, pp. 231–260). It is outside the scope of the present paper to discuss these theories here. It might also be claimed that there is nothing more to say about the location of a superposed particle beyond stating what we should expect when we measure the position of a particle in a superposition of position states. I am not sure what to say about this latter claim except that it would be hard to square with scientific realism, and that it is in the context of realism about quantum mechanics that the results I have been describing are problematic.

There are two general families of solution to this problem, or two strategies that can be employed to solve it, which I will call the von Neumann strategy and the No-collapse strategy.

The No-collapse strategy meets the empirical problem described above head on. According to it, all those goes on at the detectors, and in any observer, is just more of the same kind of deterministic process that goes on in the box. Accordingly, experimenters *do* end up in superpositions of belief states. A saving hypothesis is needed to explain why we don't *appear* to be in superpositions of belief states even though we really are. There are a number of such hypotheses on offer. (Barrett 1999, pp. 92–120, 149–220)

My interest, however, is in the more orthodox von Neumann strategy. According to it, experimenters do not end up in superpositions of belief states. A saving hypothesis is needed to explain why we don't, given that you can get a prediction that we should out of the dynamical laws of quantum mechanics. The idea is this: there are two different types of quantum mechanical process. The first process is Schrödinger evolution, which is governed by Schrödinger's equation, and is entirely deterministic. The second process is von Neumann evolution, also known as "collapse", which is indeterministic, and results in a superposed state being replaced by a determinate one.

The mathematical formalism of quantum mechanics supplies a precise description of both processes, and if we suppose that collapse takes place sometime between quantum effects (such as single particle interference) occurring, and observations of those effects, the result is empirically adequate. To completely solve the measurement problem along these lines, though, one also needs a specification of when collapse occurs. And since this specification is going to be part of our most fundamental physics, it had better be precise and non-anthropocentric. (For example, it won't do to say that collapse occurs when a quantum system is measured — that would be anthropocentric — or that it occurs when a system has macroscopic effects — that would be vague).

There are a number of such specifications, all of which have some problems. For our purposes, it won't matter which we choose. All I'm going to assume is that some version or other of the von Neumann strategy is the right way to solve the measurement problem.[8]

3.3 Non-locality and entension

Consider again the very simple experimental setup from figure 1, and think about it in the light of the von Neumann strategy. In order to make sense of what's going on in the single particle interference case, the particle has to leave the box in a superposition. That is, collapse has to be

[8] The front-runner among these specifications is probably "GRW". For a (rather critical) exposition of this, see (Albert 1992, pp. 93–111). The main problem with GRW is that it doesn't really posit collapses in the sense discussed here, but rather localisations, in which a superposed state is replaced by another, which is in some sense less superposed. This opens it to certain objections concerning probability which are identical to those given against the No-collapse strategy. (Price 1996, pp. 220–222) Nevertheless, it is a step in the right direction (from the von Neumann point of view).

occurring some time *after* the particle leaves the box. Suppose it occurs as the particle arrives at both detectors.

The period of time that's interesting for us is the time during which the particle is in a superposition of position states — that is, the period after the particle leaves the box and before the time it arrives at a detector. Granting that during this time the particle is multiply located, there are two possibilities: either the particle entends, or it pertends. If the latter, then there are two "half-particles", as it were, each of which is located on just one of the dashed lines in figure 1. What I will do now is give a reductio argument against this proposal, which I will call the pertension hypothesis.

There are two problems with it. First, it would be very hard to give a satisfying account of how the physical properties of the whole particle (other than position) — its mass, charge, or spin, for example, — stand to the half-particles. Should we suppose that each half particle carries a fraction of the mass of the whole? They don't behave as if they do — rather they behave as if they each had the whole mass of the original particle.

Second, the pertension hypothesis, in conjunction with the von Neumann strategy makes the other famous problem of quantum mechanics — the non-locality problem — much worse. Consider now the moment of collapse, when somehow the half-particles must affect one of the detectors. Everything that has happened prior to this point has been deterministic. Collapse, however, is not deterministic. Suppose that the particle will, as it happens, affect Detector 1 (and not Detector 2). Nothing about the world prior to the moment of collapse determines that this is the case.

Call the half-particle that was on the dashed line leading to Detector 1 h_1, and the half-particle that was on the dashed line leading to Detector 2 h_2. According to the pertension hypothesis, the fact that h_1 is, at the moment of collapse affecting Detector 1, *does* determine that h_2 is, at that very moment, not affecting Detector 2 — because, as a matter of law-like regularity, it's never the case that one particle affects them both. So it seems that somehow the the half-particles coordinate themselves instantaneously at the moment of collapse — so that, for example, it never happens that h_1 affects Detector 1 and h_2 affects Detector 2. Spooky action at a distance indeed.

By contrast, according to the rival entension hypothesis, at the moment of collapse the whole particle, which is located at Detector 1 and located at Detector 2, simply affects Detector 1 and does not affect Detector 2. This is strange and puzzling behaviour — that's agreed on all hands — but it's something we will have to live with in order to accept the von Neumann strategy. We do not have to accept coordination between objects that are spatially separated from one another. The pertension hypothesis multiplies mysteries, while the entension hypothesis does not. If we are to follow the von Neumann strategy, therefore, we should believe that superposed particles are entended. This concludes the reductio argument.

Compare the argument just given with my earlier discussion of elastic collision, in section 2.4. If we construed the two billiard ball system as a single object, there would appear to be a mysterious constraint on the evolution over time of that object's energy distribution. That constraint can be made less mysterious by postulating the existence of billiard balls — parts of the billiard ball system — each with a characteristic kinetic energy, and supposing that energy can be transferred between balls, but not created or destroyed.

There is no analogous explanation to be given of what happens in collapse in terms of finer parts of the superposed particle. Indeed, (as I have argued) if there were such finer parts, their behaviour would have to be even more mysterious than the behaviour of a collapsing particle. In this case we are lacking precisely those reasons I had earlier identified as our only reasons for believing in a plurality of objects. If entension is on the cards, now is the time to believe it.[9]

Some problems remain, however, which I will discuss in the remainder of this paper. One of these is ultimately empirical: what I've suggested is a way of thinking about what happens in collapse that makes it less metaphysically spooky. If I am right, in collapse something that goes on that is not action at a distance, but looks like it. The empirical problem, then, is why we don't have even the appearance of action at a distance on a cosmological scale — why, on a large scale, the universe behaves as if special relativity were true.

This is a problem of physics, rather than metaphysics. Which isn't to say that I oughtn't to be troubled by it — I am giving a hostage to empirical fortune here. But I don't know of any way of clearing up the conceptual problems of quantum mechanics without doing this.

The other two problems for the view about collapse that I have just put forward are more conceptual. They concern two slightly trickier versions of the experiment shown in figure 1.

3.4 Superposition and non-homogeneity

Figure 4 shows a box similar to that of figure 1. In this case, however, whether the box deflects the particle that goes into it depends on an intrinsic property of the particle. For example, it could be that the particle in question is an electron, and that it will be deflected up toward Detector 2 if it is x-spin up, while it will pass through to Detector 1 if it is x-spin down.

[DIAGRAM]

Figure 4: Superpositions of intrinsic states

Now suppose that an electron goes into the box in a superposition of these spin states, and that collapse does not occur in the box (for same reasons as for the box of figure 1). Then, if we apply the same reasoning as used above, the electron leaves the box on both the dashed and dotted lines, and moreover is wholly located on both.

[9] An alternative to believing in entension in this case is to believe that the spatial parts of a superposed particle — h_1 and h_2 in my example — do not act on each other at the moment of collapse, but rather that the whole superposed particle acts on both h_1 and h_2 — a kind of "downward causation". That eliminates the action at a distance, because the whole particle is located both where h_1 is and where h_2 is (it's partially located in both places). One might have objections to the possibility of downward causation. Even setting those aside, it's not clear to me that this scenario offers more explanation of what's going on than my proposal that the particle is entended.

By now, however, the electron's x-spin is entangled with its position. If the electron is finally observed at detector 1, it will always be observed to be x-spin down; by contrast, if it is finally observed at detector 2, it will be x-spin up. So the electron in this example is not only entended, but non-homogeneous. It's spinning one way on the dotted line, and another way on the dashed line. This is why I needed to deal with the problem of non-homogeneity in section 2.3, and couldn't take the easy way out by accepting that if there are any entended objects, they must be homogeneous.

3.5 EPR-type cases

I said above that the von Neumann strategy makes the non-locality problem worse. The reason that this is so is that the types of cases described above are not the cases that are usually dealt with in discussions of the non-locality problem. Normally, when people discuss the non-locality problem, they have in mind slightly more arcane experimental setups than the ones I have considered so far.

[DIAGRAM]

Figure 5: An EPR-type setup

In figure 5, two particles are emitted in such a way that the intrinsic properties of those particles are entangled. Suppose for example, that the particles are electrons, and the boxes affect them differently depending on their x-spin, as in the previous example.

The source emits the electrons in opposite directions. This time however, the left hand box deflects x-spin up electrons, passing them through if they are x-spin down; the right hand box does the reverse, deflecting the x-spin down electrons, and passing through the x-spin up. Again, the source emits the electrons in a superposed x-spin state — but the electrons will always be observed at D1 and D1a or at D2 and D2a, never at D1 and D2a or D2 and D1a.[10]

The quantum system consisting of the two particles is in what is called a "non-separable" state. The state of the whole system allows us to predict with certainty that the particles will always be observed at D1 and D1a or at D2 and D2a, never at D1 and D2a or D2 and D1a. You can't predict that, however, from the respective states of the two particles themselves. In metaphysical language, non-separable states of quantum systems fail to supervene on the states of their proper parts.

As before, the particles leave the boxes in a superposition of position states. The particle that leaves the source heading right (call it Righty) travels along both the both the dashed lines

[10]It could also be that the particles are photons, and the intrinsic property in question is polarisation. The source emits unpolarised photons in opposite directions. The box on the left sends horizontally polarised photons to D1 and vertically polarised photons to D2. When unpolarised photons go through the boxes, half the time they appear at D1, and the other half at D2. The box on the right does exactly the same thing, sending photons toward D1a and D2a according to their polarisation. There are sources (for a detailed account, see (Maudlin 1994, pp. 11–14)) that will do this in such a way that the photons are always observed to, as it were, come out of the boxes the same way — that is, always affecting D1 and D1a or affecting D2 and D2a, never affecting D1 and D2a or D2 and D1a.

leading to D1 and D2. The particle that leaves the source heading left (Lefty) travels along *both* the dashed lines leading to D1a and D2a. Suppose the moment of collapse is just before the particles affect the detectors, and suppose that, after collapse, the two particles will affect D1 and D1a respectively. As before, at the moment of collapse, there seems to be instantaneous action at a distance between D1 and D2.

But there also seems to be action at a distance between D1 and D1a. Everything that has happened in this setup prior to collapse has been perfectly deterministic, and has yet failed to determine that a particle will affect D1a (or D1, D2, or D2a, for that matter). When Righty affects D1, that determines that Lefty (who could, given everything that's happened so far, affect D1a or D2a) is right at that moment affecting D1a, and not affecting D2a.

That's the type of setup that's normally discussed under the heading "the non-locality problem". The von Neumann strategy makes matters worse in that it makes it seem that there is action at a distance even in single particle systems. I've suggested a way to deal with this, by invoking entension. At the worst, this means that my version of the von Neumann strategy doesn't have to make the non-locality problem any harder (though it doesn't make it any easier either).

But if that was all I was saying, then I'd open myself to a troubling objection: if we're stuck with action at a distance anyway, then what does it gain to have less rather than more of it? Is there anything I can say about entension that will make the setup of figure 5 less puzzling?

In this case, the apparent action at a distance is between two distinct particles, Lefty and Righty. So it won't help to claim that Lefty and Righty entend. But it would help to say that the whole system composed of Lefty and Righty does. I propose that in these kinds of setups, the source does not in fact produce two particles, but a single entended object, a two-particle, which behaves almost exactly like the mereological fusion of two particles.

The two-particle is emitted by the source and begins travelling along both the solid lines toward the boxes. At this point it is already wholly located in each of two different places, on both lines. After passing through the boxes, it is wholly located in each of four different places, on all four dashed lines. At the moment of collapse, the two-particle "makes up its mind", in accordance with the laws governing collapse, that it is going to affect D1 and D1a, and not D2 and D2a. There's no need for spooky action at a distance, because the two-particle is not at a distance from any of the things it affects.

This proposal is really nothing more than the application of a fairly traditional metaphysical idea — the idea that the fundamental ontology of the world consists of substances — where that means things that exist independently of each other. The elements of a non-separable quantum system don't seem to exist independently. Therefore, they are not substances, and if you buy into an ontology of substances, then they are not part of the fundamental ontology of the world. This is, of course, an extra argument for my proposal — you don't have to like substance ontologies to want to solve the non-locality problem in this way.

4 Conclusion

The views I've put forward about quantum mechanics are necessarily a bit tentative. I haven't tried to decide the issue between the No-collapse and von Neumann strategies; as I've pointed out, there are open problems for even the best version of the von Neumann strategy (see footnote 8); and I've been applying my arguments only to non-relativistic quantum mechanics. Nevertheless, I think that what I've done is worthwhile metaphysics. Even if non-relativistic quantum mechanics isn't likely to be true, it's close enough to what's likely to be true for it to be worth knowing what it would take for it to be true. And if it's close enough to the truth, then we'd be well advised to keep entension in our metaphysical toolkit.

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