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Quantum Mechanics and Ontology

by

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Abstract:

This is a philosophy of science paper aimed at mapping C.B. Martin's ontological theory of dispositions and manifestations onto experiments in quantum mechanics, with hopes of generating a plausible view of the universe in general.

Part one focuses on the general methods available to philosophers, in hopes of establishing guidelines for doing such philosophy as I hope to do. Part two is centered on the Armstrong/Martin debate, the result of which is that we find Martin's ontological theory preferable to Armstrong's. Part three is the actual attempt to map Martin's ontology onto some physics experiments, with prime focus on the so-called double-slit or interference experiment.

Acknowledgments:

My thanks to Dr. John Heintz and Dr. Brian Grant for encouraging me to investigate skepticism and the merits of skeptical philosophy. And my thanks also to Dr. Charlie Martin, for urging me to "Forget that stuff... there's work to do!"

Dr. Mark Migotti and Dr. Ranga Sreenivasan deserve praise for their efforts in making this paper both readable and substantive. Any failure in either regard is purely the fault of the author.

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Introduction

This is a paper in distinct but related parts. The general idea I wish to pursue is this: by venturing into the realm of quantum mechanical physics, we might find some evidence for particular ontological views, and vice-versa (we might find ourselves better able to cope with the results of the experiments if we are suitably armed with a general theory of the universe). We shall be working on the border between physics and philosophy, which presumably makes this an excursion in philosophy of science. However, I do not intend to talk about science other than in reference to particular experiments.

I will spend some time sorting out concepts which will be required in order to understand the metaphysical system I wish to present at the end of the paper. Rather than dive headfirst into the actual metaphysics, I would like to begin with more epistemological concerns. Doing ontology without a parallel analysis of the epistemic fallout would be bad practice (and confusing to the reader). Skepticism in many forms will be discussed, as it plays a central role in metaphysics. This is not so much to abate the skeptic's worries as to arm ourselves with skeptical tools, Occam's Razor being the main.

With such philosophizing comes the crystallization of some ideas which lead to the acceptance of certain elements of metaphysics and the rejection of others. Without such investigating, one is liable to philosophize with a great deal of unconscious baggage - predilections for certain things, particular world-views, etc. (What's the "etcetera"? Ask Wittgenstein.) Once this task is accomplished, we can move into the world and develop a (more) complete picture of what it is like.

With such groundwork laid out, I intend to investigate the Armstrong/Martin debate. It is my intention to analyze their theories and their methodologies in hopes of finding an acceptable ontological theory. We ought to stand on the shoulders of giants if the local giants avail themselves.

With the "philosophy" done, we can move into the world and see how the philosophical theory fits with puzzling physics experiments. If the fit is good, we might see this as evidence that the philosophy is sound. After all, describing the way the world operates is the chief goal of the ontologist. But this is "mere philosophy". Perhaps offering an explanation for the experiments at all is of greater importance.

I will utilize a variant of Martin's disposition/manifestation ontology to offer possible explanations for the double-slit experiment as well as the violation of Bell's theorem by quantum systems. What arises is an original interpretation of the Schrodinger equation and other laws of nature.

Part 1 Many Forms of Skepticism

Undertaking a philosophical enterprise is in some ways easier if one knows nothing about it. The informed philosopher has an endless array of questions before him; issues of which a neophyte is happily unaware. Often enough, a problem at hand can be distilled to some or another form of the problem of skepticism. Succinctly put, the *res horribilis* is this: how are we to invade with sufficient cunning the problems which lie before us and yet remain free from the devastating burden of outright (Cartesian) skepticism (which leaves us "knowing" virtually nothing)?

The methodology of the philosopher depends on the answer to this question. DesCartes was hobbled by it, Hume accused Locke of avoiding it, Wittgenstein dedicated his later philosophical life to it, and to what avail? The question of skepticism seemingly lies unresolved (the upshot being that a singular "philosophical method" is yet to be unanimously accepted).

As the previous paragraph indicates, my hopes are not high for the project of identifying a sure-fire philosophical method. Roughly speaking, I think metaphysicians can be cut into two camps - "skeptics" and "others" (skeptics and what? Shall we call the other camp "non-skeptics"? Is that a little insulting?). Generally speaking, the "skeptics" draw our attention to the fact that we cannot prove that something or other is true, and from there begin to philosophize. (Wittgenstein's famous "Beetle in a Box" strikes me as this sort of device[1]...). This is necessarily a "negatively" oriented form of philosophy, the results of which are generally statements about what we don't know, rather than what we do.

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[1] Wittgenstein 1, §293

For the "non-skeptic's" part, we find a more straightforward approach - the approach of Locke, and also of Schopenhauer, whose "Fortress of Skepticism" none can forget. Skepticism is largely ignored by such folk. This is not to say that the possibility of error is not minimized as much as possible through careful conceptual analysis. Our so-called "non-skeptic" does not proceed by grandly announcing transcendental truths while staring at a crystal ball. Rather, we find a form of philosophy that is akin to jigsaw puzzling. The method relies on the belief that nature has provided us with means to explore our world, and that the stories we tell about the world (after sufficient examination and thought) might be "True". Keynes' summation of Newton is appropriate here:

> **"... he looked on the whole universe and all that is in it *as a riddle*, as a secret which could be read by applying pure thought to certain evidence, certain mystic clues which God had laid about the world to allow a sort of philosopher's treasure hunt..."[2]**

This is necessarily the approach of the analytic ontologic philosopher. That we all (or is there only me?) might be brains in vats is a fact that we *must* largely bypass in our travels if developing a picture (or *story*) of the world is our goal.

This is *not* to say that skepticism plays no role in philosophizing about ontology. Indeed it will be one of the tools used (an analytic philosopher without skepticism is hard to imagine). If this seems odd, consider what skepticism is. Roughly put, skepticism is no more than *doubt*. A skeptic's general method is to point out a particular idea and suggest that perhaps it is incorrect. This in itself is what might be called negative philosophy - showing what we *don't* know, rather than postulating that we *do*. This is DesCartes'

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[2] Keynes, p. 29

legacy, and philosophers have wrangled with it ever since (and before, to be sure - Chuang Tzu examined the philosophical repercussions of dreaming he was a butterfly (and not knowing ever after if he was a butterfly dreaming that it was a philosopher) 500 years before Christ.). The positive philosopher, for his part, must provide enough grounding for his ideas that the skeptic is reasonably satisfied, but more than that, the positive philosopher must be sure to apply enough skepticism in the right places such that his theory is not mere fools' play.

Balancing between the Nirvana of working without any philosophical restraints and the abyss of outright skepticism is the metaphysician's task. I point this out not in order to make an epistemological point, but merely to render the rest of this investigation somewhat more readable. The Armstrong/Martin debate is fraught with epistemology, though neither Armstrong nor Martin tend to discuss it very often. What might initially be taken to be simplistic tendencies are more often than not extremely *subtle* tendencies. We cannot fully understand the positions of such philosophers without an analysis of their convictions. The following elaboration of skeptical styles is intended to help develop an eye for the subtle but critical elements of metaphysics. So armed, we can not only understand philosophy better, but actually do better philosophy ourselves.

Anti-Realism as a Form of Skepticism

I would like to make reference to a distinction which we will be forced to return to a number of times. The concepts of realism and its philosophic inverse, anti-realism, are widely understood. Realism might be broadly defined as the belief that certain unobservables exist in an ontologic way. Anti-realism is thus the belief that unobservables ought not be acknowledged. A realist, then, might hold that "gravity" is a word we apply to the concept of masses attracting (or of curved spacetime, to be Einsteinian rather than Newtonian), and that "gravity" is a part of nature which we have managed to piece together on our treasure hunt. The anti-realist is less optimistic, preferring a stance which is more neutral with regards to believing that we actually know what we are talking about when we say "gravitation." An anti-realist prefers to utilize "gravity" as a *way of thinking* about how masses act, remaining uncommitted to the existence of some unobservable "force".

Peirce was deeply unimpressed by anti-realism, writing, "In a recent admired work on *Analytic Mechanics* it is stated that we understand precisely the effect of force, but what force itself is we do not understand! This is simply a self-contradiction."[3]

If this is the case, then why bother with anti-realism at all? For one reason, the most widely accepted physics-based ontology of the twentieth century was that of Niels Bohr, himself a devout anti-realist. Bohr felt that he had physical reasons for being an anti-realist (which will be dealt with in detail in part three). Another reason is that it is *not* always clear that we know what we are talking about when we use any particular technical term. Peirce's example is clear but perhaps a bit simplistic. It may be easy to say that we

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[3] Peirce, p.35

know what a force is, given that force is a fairly concrete notion (a mass under acceleration). Can we be so casual with a more "abstract" term? "Potential" is going to play a central role in our later discussions, and as we will see, it is not clear that we can say with certainty that potentials are "real", or "spatio-temporal". As such, the anti-realist creeps back in with the suggestion that potentials ought not be considered as "real". An anti-realist gains more purchase on more abstract ideas, and because of this, is going to feel that he has quite a lot of purchase in the arena of the metaphysical.

This is our first contact with a skeptic in scientist's clothes, and it is an important one. Skepticism with regard to "reality" (or rather, our ability to penetrate the veil of reality) is anti-realism, and we need to be on our guard for it. This is not to say that anti-realism is necessarily bad or wrong, but we need to know where arguments are coming from and going in the sphere of ontological philosophy. As we proceed, I hope to sharpen both the realist and anti-realist positions to honed forms. This is not so much in order to promote one over the other as to help in developing the soundest ontologic commitments we can.

I would like to mention a distinction which I have long harboured, but which seems to be ignored in the literature. The anti-realist is concerned about things known as "unobservables". It is generally assumed that all unobservables are roughly equal, in that they are unobservable, and thus to be regarded with skepticism or neutrality. This may stand. However, I would like to claim that there are two types of unobservables (with which the anti-realist can do as he pleases). The first type of unobservable is something that is in principle observable, but which we lack the technology to observe. I would like to call such characters In-Principle-Observables (IPOs). An electron, for example, might fall into this category. We have so far been able to "detect" electrons by inference. They leave footprints in cloud chambers, for example. We see *effects* of something (whatever it is) we call "electrons". The realist suggests that the effects are effects of a something, and that we ought to believe in electrons even though we cannot see them. The anti-realist takes a less ingenuous stance, suggesting that what we have seen is the effect, but that the cause, as such, is not itself known.

The second type of unobservable I would like to call "In-Principle-Unobservables" (IPUs). IPUs are concepts which we hold as critical to our understanding of the universe, but which, unlike IPOs, we cannot in principle hope to directly observe. Such things as "Force" and "Energy" will fall into this category. These are things which we have developed as central to our physics theories, but just "what" they are is perhaps debatable.

Given this separation of unobservables, what is the anti-realist likely to do? If a realist like Pierce is correct, then an IPU like "Force" is nothing over and above a mass under acceleration, and thus, we may claim to know *more* about an IPU like "Force" than we do about an IPO like an "electron" (the full "definition" of which we are yet to give). Of course, the anti-realist combats such a claim, denying the truth of Peirce's assertion. An anti-realist might well say that the opposite is true - we have some undeniable physical grounds for asserting the existence of electrons, but we haven't directly observed them and so should remain cautious at the very least when it comes to adding them into our ontologic inventory. It would be claimed that a notion like "Force" is on much more slippery metaphysical ground - it is a concept which we apply to certain behaviours, and the only reason to assert the existence of the something called "force" is that we desire a reductive description of the events in the universe.

Of course, desiring a description of the physical situation is the motivation of calling something an "electron" as well, but the anti-realist might argue that witnessing the effects of an electron gives us reason to posit that *something* was there, whereas in the case of a "force", we are merely concocting a story. The claim would be that we don't know what a force is, but that we apply the term to certain situations in which masses accelerate, and presumably, smarter metaphysicians from Pluto would have a totally different story about "force" (though presumably they would still want to tell a story similar to our own when it comes to IPOs like electrons).

The distinction between In-Principle-Observables and In-Principle-Unobservables is a technical one, and perhaps one that most anti-realists would see as unimportant. It plays a role in ontology, though, because if we wind up introducing IPUs at critical junctures, many realists and anti-realists alike will be unhappy.

Occam's Razor

We require a tool to fight the anti-realist, and to do good philosophy in general. I propose Occam's Razor for the task. It is usually constructed as a tool for theory selection, wherein simpler theories should be preferred to more complicated ones. However, I would like to use a slightly more subtle (or in any case more useful for my purposes) version. I think we are entitled to suggest that a theory with unnecessary hypotheses is less preferable than a theory which has only required hypotheses. What this means is that if we cook up a story about how some element of the universe operates, we should keep the story as free from "clutter" as possible. Any excess terms or concepts ought to be discarded. This should perhaps be called "Armstrong's Razor", because I think D.M.Armstrong uses this principle with more vigour than anyone else. It is a method designed to ward off the anti-realist, primarily by keeping everything in a theory as necessary as possible. By analyzing whether we truly require any particular part of the story, we limit the anti-realist's campaign to things we are confident about. That is, we can write off the anti-realist (more like Peirce did) because of our certainty of the concepts in our theory, and the necessity of those concepts.

Part 2 The Armstrong/Martin Debate

Armstrong's Ontology (The Tightest Attempt)

Rather than start from scratch in both the epistemic and ontologic realm, we can turn to the work done by others in the field. Analyzing what others have presented is probably the fastest way to come to positive conclusions. I would like to begin with ideas presented by D.M.Armstrong, because he offers with sparkling clarity both a positive package (ontology) and some caveats about the whole enterprise (epistemology).

I call Armstrong's work the tightest attempt because his theorizing has always been a sort of skeptically-oriented venture. This is not to say that Armstrong is someone we want to brand as a "skeptic". Rather, Armstrong must be seen as an anti-skeptic - someone working on a positive philosophy *despite* skeptical challenges. His intention is not to offer skepticism, but to offer a theory against which a skeptic has little to say. His hope is to provide a theory of the world which the skeptic cannot criticize as "unreal". What this means is that Armstrong is working against a particular style of anti-realist - a skeptic with regard to our ability to generate true stories about nature.[4]

To this end, Armstrong suggests we "...remain with naturalism, defined as the doctrine that all there is is the world of space and time."[5] This is tantamount to claiming that abstract objects ought not be part of a theory of the universe. Armstrong prefers to stay within the limits of spatiotemporality simply because we cannot clearly describe what the non-spatiotemporal might be like. Lack of clarity on such things opens the door for a skeptic, who might claim that it is unlikely that we would be able to generate a true story of the universe if we cannot describe fully some aspect of the story. That is to say, the

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[4] Rorty, for instance, falls under this heading in Philosophy and the Mirror of Nature

anti-realist gets a foothold if abstract objects are a part of our ontology, with the simple claim (correct or not) that we cannot be sure that what we are talking about is part of the universe. In order to avoid debating the anti-realist, Armstrong keeps his theorizing within the stated grounds.

Armstrong's ontology looks a bit like what we would be used to if we have spent time as or with scientists. He talks of the laws of nature, and he talks of substances[6] (chairs, protons, etc.). And with substances and laws, he builds a picture of the world. It is an easy ontology to grasp intuitively, as we are used to talking about things like tables and the things that they do, like falling when dropped from the top of a building. We have mathematical statements which seem to describe such situations, and we call them "Laws of Nature". This is where Armstrong makes a firm commitment which we need to ponder. He suggests that "Laws of Nature" are universal but not abstract. This must sound strange to a seasoned philosopher, as the two words are often enough associated that it may initially seem absurd to suggest universality without abstraction too.

The key to understanding Armstrong's views lies in his opinion of abstract objects: his commitment to the removal of abstracta from ontology is *total*. We have in this understanding both the positive direction of his ontological theorizing and the locus of his criticisms of others. We might see it as a use of Occam's Razor - Armstrong cuts out the complications of abstract entities in favour of a simpler view. He is a skeptic with regard

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[5] Armstrong, Martin, Place, P.90

[6] This is loose talk, and it is mine rather than Armstrong's. Armstrong uses the term "state of affairs" as a sort of example situation. It breaks down to the entities in question and their interactions - "stuff"(matter, substance - whatever you want to call the "stuff" that is in the universe) and "laws". I prefer slightly less rigorous terminology as it aids in gaining a quick understanding (which is all I can hope to get across, as the writer of a not-too-long overview).

to the abstract, and his skepticism leads him to take action against the abstract.[7] This, he hopes, will leave no room for skeptical *questioning* of the theory. Thus "tightness" is achieved.

"Law of Nature" is an easy concept to grasp, at least in a shallow way. Why do masses attract each other? It is a "Law of Nature". We tend to tie mathematics to concepts in question, à la Newton. Armstrong's claim is that there need not be any other thing in the universe than the masses in question (other than the universe and its particular space-time fabric). That is, there aren't masses AND an abstract law waiting for instantiation, according to Armstrong. The masses just behave in a certain way. We call it a law because all masses seem to act similarly in this universe. It can be called "universal" because there is no apparent deviance from the law (anywhere in this universe). However, we are not entitled to associate this notion with any of the usual Platonic baggage. Armstrong's "universals" exist *only* in instantiation - there is nothing over and above the instantiated law.

Let us describe a relatively simple situation in what I take to be Armstrongian terms. Consider table salt (sodium chloride in its solid form). Why does salt dissolve in water? Ask a chemist. You will be told a story about polarity, bond energies, entropy, ionization energies, and other technical notions which go into the explanation of why some things tend to dissolve in water (or diethyl ether, or oil...) and others don't. The explanation breaks down to matter (stuff) and laws that govern how matter interacts, each and every time, in each and every case. To cash this in Armstrong's terms, we have a

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[7] Here we must be careful with our terminology - a gentle skeptic says "After investigating, I'm still not sure about X, so let's be careful in talking about X." A really hard-core skeptic says "After investigating X, I'm still not sure about it, so let's not count it as knowledge."

categorical property (solubility) which is reductively explained, the reduction ending with the most basic laws of nature, the laws governing the interactions of the quarks. From the quarks we build protons and neutrons, (obeying the laws in question), and the protons and neutrons interact in a certain way. Up the causal chain we go right to the interaction of salt and water. The property of solubility is due to properties of the molecules, which are due to properties of the atoms, which are due to properties of quarks, which are presumably due to the laws of the universe being the way they are and not some other way.

Another example. Armstrong sees a fragile goblet as composed of certain molecules arranged in a certain way, and because of the laws of physics, the thing has a property we call fragility, which in Armstrong's view reduces to the molecular and the nomological. The glass has a certain molecular structure which is easily destroyed. In Armstrong's ontology, the explanatory work is done at a completely reduced level - complex interactions break down to simpler ones, in terms of charge, mass, etc, and the laws which govern them. There is nothing else to speak of, no extra "readiness" in the glass - "readiness" or "disposition" is an abstract notion which we humans associate with the categorical properties of the glass. Thinking in this way, "fragility" becomes in some sense an ontologically superfluous notion. Occam's Razor is invoked, and we are left with matter and laws. If you want "fragility" hanging around as well, you are perhaps entitled to it, but don't think of it as anything over and above the categorical, anything over and above the physical story.

This ontological program is easily acceptable to many scientists, who are in general perfectly happy to refer to matter and laws which govern it, without any particular philosophizing about either entity. (It could be argued that this is what science is all about - prediction using "laws" rather than explanation of the laws.) The world is broken down into things and behaviours of things, whether the relatively "simple" interaction between masses (which we name gravity) or the relatively complex interactions of university students and alcoholic beverages. With such a view we can develop theories about the world which are predictive of a wide variety of circumstances, and this of course is the task of science (observation and prediction). Scientists need no more than a set of equations which are predictive of the outcomes of experiments. The hope is that we'll find a set or sets of equations which can handle everything we come across. We see Armstrong as a scientist's philosopher, much as Sir Karl Popper was.

Could ontological philosophy be so easy? All we had to do was banish the abstract in order to generate a sensible "scientific" picture of the universe? Unfortunately, things are not so simple. C.B. Martin has developed a case wherein it is hypothesized that there are some particles of an element heretofore unknown to us (let us call it element X) floating around on the far side of the universe.[8] These particles have never yet come into contact with any other types of matter. If there is to be an interaction in the future with, say, the element fluorine, then the statement "Element X will react in an exothermic fashion with fluorine." is either true or false. Martin's suggestion is that Armstrong cannot agree (or disagree) with the truth of such a statement, for it would imply the existence of an abstract law - something which would make the statement true (or false).

[8] See Armstrong, Martin, Place p.95

Armstrong cannot claim that the event itself makes the statement true, because the event has not happened yet. (An epistemic note is well in order: Martin has "snuck" a Russell-style doctrine of so-called "Truthmakers" (Russell's term was "verifiers") into the example. Martin requires that any statement having a truth-value must correspond to something in the world, which gives it that truth value. Russell framed it thus: "...in the case of a true belief, there is a fact to which it has a certain relation..."[9] I do not intend to suggest that the principle is a bad one; merely that the game ought to be known to all at the table.)

Armstrong requires that there be a law of nature regarding the interaction in Martin's hypothetical case. (If there is no law governing any proposed interaction, there cannot be any such interaction.) The Armstrongian law, as non-abstract, needs to have been instantiated at some point prior to this particular meeting of particles (otherwise we can't call it a law - laws cannot exist in an abstract way!). Here we find part of Armstrong's explanation of what it is to be a universal but non-abstract law - it must be previously instantiated, lest it be abstract. Martin argues that it just *could* be the case that there has been no such prior instantiation and yet the statement about element X remains true. If this is so, then Armstrong is in some trouble. [10]

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[9] Russell, p. 166

[10] Of course, it may NOT have a truth value, just as the proposition "It will snow tomorrow." might be construed as having no truth value. I think Martin's answer would be that we ought not confuse the ontologic (the truth) from the epistemic (our knowing it). But there are other answers, and a refutation of Martin's epistemic commitments would also be a refutation of Martin's case. Epistemology rears its ugly head again... However, Armstrong accepts the Russellian epistemology (in some or another guise), so he has his work cut out for him. Additionally, it is difficult to conceive of trying to concoct an ontology without acceptance of such an epistemology. A Rortian approach, for instance, is totally out of the question. Indeed, some or other element of foundationalism is probably requisite for ontologers - the belief that the world gives us information, and that we can theorize about the mechanistic aspects of it seems to be THE key ingredient in what might be considered analytic ontology. Schopenhauer did ontology too, but his method was much more "internally" focused - you can't call your seminal paper

Armstrong *requires* prior instantiation so as to remain free of abstract laws. His ontology would be internally inconsistent if it did not. (One can imagine a position much like Armstrong's (stuff and laws) but including abstract laws, in which event, Martin's case is less decisive - if we can utilize the term "law" without requiring instantiation, we are off the hook of prior instantiation but onto the hook of abstraction. Thus Armstrong stands his ground...) Martin's case must be seen as damaging to Armstrong's ontological commitments. The requirement of prior-instantiation is far from acceptable if we agree that the statement about element X has a truth value.

An effort might be made by a positivist of some form or another, for whom meaning lies in the method of verification, say. Such a one might argue that as Martin's case is unverifiable, it is meaningless. In conversation, Martin calls this the "If pigs had wings" argument, and his rebuttal is that if pigs had wings they *still* wouldn't fly. What does Martin mean? The crux of the issue is skepticism, and I offer here a short digression on the matter.

Positivists launched a sort of pseudo-empirical philosophy not in hopes of being a particularly skeptical group, but rather hoping to *evade* the skeptic with their methods. The goal was that philosophy could be developed with sufficient tightness of method that the skeptical noose could in a sense be slipped. That is, they hoped that positive philosophy could be done without the skeptic constantly questioning whatever was being offered. Why then does Martin, the consummate anti-skeptic, reject their lines of thinking? Simply because they cut out more than he is comfortable with. The positivist

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"The World as Will and Representation" otherwise! We came neither to praise nor bury Schopenhauer, nor argue the merits of analytic ontology. We work in the mundane - trying to tell a stroy about how the world would be *without* us.

becomes a skeptic in his attempt to refute the skeptic. Dismissing things as nonsense, the positivist is nothing more than a "sense" skeptic! (A.J.Ayer, for instance, falls into this category). To suggest that a statement has no meaning because it is not verifiable is to be skeptical with regard to meaning. Methodology requiring verifiability as the root of meaning by nature disallows venturing forth with a metaphysical theory. As positive metaphysics cannot be done with such an attitude, Martin dismisses the positivist.

Martin's line is *truly anti-skeptical*, the modus operandi being more one of outright dismissal than anything like evasion. The ontologically minded metaphysician is attempting to build a picture of the world, and at the end of every sentence stands some form of skeptic, ready to pounce. What is the defense, then, if positivism cuts out too much metaphysical meat? We can add some subtlety (and substance) to Martin's anti-skeptical stance by borrowing from Wittgenstein (whom I also consider an anti-skeptic (though he is skeptical of the skeptic, it seems... is this metaskepticism?)). Wittgenstein asks, "Doesn't one need grounds for doubt?"[11]and with this question attempts to dismiss the skeptic. For if one is entitled to request grounds for belief, we should also require grounds for doubt, seeing that both have the same epistemic standing. What I mean is this: if the skeptic thinks his doubts have philosophical power, he must also admit that the anti-skeptic's doubts (about skepticism) have power as well. It is a philosophic tie. The skeptic cannot rationally assert that his doubts about the world are more grounded than my doubts about his doubts (unless he has evidence - but then he is a scientist rather than a skeptic.). If this is so, then Martin's case of element X can only be rejected on what turn out to be purely skeptical grounds (the argument of "You can't prove that that's a real

[11] Wittgenstien, L. On Certainty, p.18

case!" Compare this to the logical fallacy of assuming that a lack of evidence for proposition A is evidence for A's being false.), and we are not inclined to be persuaded by such.

With these considerations in mind, Martin's case appears to stand.

If we agree that Armstrong's stance is admirable but in the end self-destructive, we might attempt to keep the good and discard the bad. Armstrong's anti-skeptical stance is his downfall, wielding Occam's Razor with such vigor that even his own theory is rendered helpless. I think that Armstrong's intention was to remain impervious to the skeptic, particularly the anti-realist (the skeptic with regard to "realist" laws, as it were). By removing abstracta from his ontology, he hoped to weld the seams against skeptical lines of questioning. This welding *is* successful, and *does* indeed limit the anti-realist's ability to gain purchase. Having no reason to put forward his skepticism about what we are talking about when we say "Law of Nature" or some equivalent thing, the skeptic goes home empty-handed. However, Armstrong's welding is too seamless - we wind up disavowing not a skeptical case but just the opposite - a "might this not be *true?*" argument rather than a "might this not be *false?*" argument (the general form of the skeptical argument). We must therefore endeavour to unfold just a little bit more of our skeptic-proof blanket. An obvious avenue of exploration is the acceptance of abstract objects into ontology, and this is the road I will travel (from Armstrong's point of view). (Armstrong is apparently working on a book about Truthmakers, taking the epistemic road to re-rendering his ontology. I prefer what Martin calls the "low road" - work in ontology.)

Martin's Ontology (A Different Kind of Tight Attempt)

A candidate successor to Armstrong's is Martin's theory of dispositions and manifestations. Again, let us proceed by example in order to highlight the relevant concepts. We expect that salt will dissolve in water. Given a teaspoon of salt and a glass of water, we know what will happen if we put the salt in the water. It will dissolve. It is no stretch of normal conception to say that the salt is *disposed* to dissolve in the water. In Martin-speak, the salt has a disposition we might name "water solubility". The manifestation of the disposition occurs when we actually place the salt in the water. And here is *the* critical distinction for understanding Martin's view: the disposition exists before you ever put the salt in the water. The dry salt has a *readiness,* if you will, to dissolve in water. The *manifestation* of the disposition is the salt's dissolving. The manifestation requires both salt and water to be present. The salt and the water are "reciprocal disposition partners" (the water has a disposition we might name "salt solvency"). The salt and the water carry independent dispositions, both of which are mutual partners, both of which must be present for manifestation. Water solubility cannot be demonstrated in turpentine!

The distinction between disposition and manifestation must be clearly understood before continuing. Our other example from before was a crystal goblet. One of the properties ordinarily attributed to a crystal goblet is fragility. We mean by "fragile" that the goblet might easily be broken. (Translated into Martin-speak: the goblet has a readiness or disposition for breaking.) If our goblet falls from a table, it accelerates under the force of gravity and smashes into innumerable pieces upon contact with the ceramic tile floor. The manifestation of fragility is the destruction of the glass. The ceramic floor is the reciprocal disposition partner for the manifestation of the fragility.[12] The fragility exists at all times, right up to the point that the glass actually breaks.

The disposition to break is terminated at the time of breaking. The disposition of dynamite to explode is terminated at the time of exploding. Compare: The disposition of salt to dissolve is *temporarily blocked* when it dissolves. One can let the water evaporate from the glass, getting soluble salt again, but one cannot put dynamite back together "post-manifestation", nor stick a goblet back together once smashed (without glassblowing - in a sense making a new goblet, but let us not pick nits). In some sense, the disposition for solubility does not end (unless the salt "ends") whereas the disposition-line for explosion or breakage (fragility) does end with the first manifestation. (Other dispositions are neither blocked nor destroyed when manifest - the stability of a bridge, for instance, might be said to manifest when a heavy truck goes across, then once the truck is across, the dispositional state (non-manifest) is "restored".)

Dispositional theory is reductionistic, and for all the chemists out there (of which I am one), we can if we so desire (and I think we should desire this) explain the disposition of salt to dissolve in water via our notions of electromagnetics and thermodynamics. But surely a dispositional picture is available here too. We can break down molecular behaviour into dispositions if we want to conceive of the world in that way. Charge is a dispositional sort of thing, for instance. In a very real sense, "charge" is best summed up as a concept we apply to entities which manifest certain behaviours under certain conditions. That is, charge manifests itself when the relevant dispositional partners are

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[12] Obviously, this is a bit simplistic. There are many conditions which must be met for the manifestation of fragility. The glass must hit hard enough, and possibly at the right angle, thus the full dispositional

provided (i.e. an electric field). Electronegativity, electron affinity, atomic radius, all of these things are dispositional characteristics. Silicon, for instance, does not (is not *disposed* to) form very strong pi bonds because it is too big to do so successfully. These sorts of dispositions may depend on other, lower level dispositions, of course.

Bringing together relevant dispositional partners yields some sort of manifestation, which in turn may generate new disposition lines. I have dispositions different from those of a rock, though I am made up of the same things - protons, neutrons, and electrons. The manifestation of some dispositions yields new dispositions (human beings' disposition to gain new dispositions fits this description).

Martin says that there is only one level of reality. I think a rewording of that would be that all dispositions are equally ontologically footed, from the more simple quantum behaviour of electrons to my (more complex) insatiable desires for beer and pizza. From the simpler dispositional property of charge up to the more complex dispositional property of laziness - all are equally ontologic. Name a property, you've most likely named a manifestation. And under the manifestation are the dispositional partners.

The key to this theory is that dispositions (or readinesses) are real; the prime units of ontology, and manifestation occurs when reciprocal disposition partners are provided. This is Martin's view in its plainest clothes. We will dress it up more as we proceed.

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description must include all of these factors. This in itself is not a problem, but would complicate the example unnecessarily.

Discussion of Martin and Armstrong

It cannot be over-emphasized that Martin and Armstrong are both realists. They happen to be different types of realists, however, and it is worth spelling this out. Martin considers "disposition" to be the prime unit of the world. We can contrast this slightly puzzling view with Armstrong's, who, I believe, is better called a *substance* realist - believing in substance (what we might *ordinarily* call "matter") as the prime unit. For Armstrong, there must be a something at the bottom of the causal chain, and the suggestion that the something is a disposition is not acceptable. So we have two died-in-the-wool realists, but their conceptions of the universe are indeed very different.

From a perspective such as Armstrong's, the whole of Martin's work *might* be viewed as epistemology; conception-oriented rather than world-oriented. Understanding this element of Armstrong's stance is absolutely critical. For Armstrong, abstracta are superfluous, playing no role in the causal stories we want to tell (and thus cut out by Occam's Razor). Martin rejects this claim in high style, countering with the proposal that at the lowest level, each of Armstrong's "categorical properties" is in fact *logically identical* with a particular disposition. If this is indeed the case, we cannot differentiate between the categorical and the dispositional, cannot claim dispositions to be an "epistemic entity" while categorical properties remain "ontologic". Armstrong can attempt to reject this claim on the grounds that categorical is not what drives the system - it's merely a concept we associate with the behaviours we witness.

Of course the notion of "dispositions", "intrinsic readiness", or "intrinsic capabilities" ("capacities" as N. Cartwright likes, etc.), is exactly the kind of thing Armstrong worked to avoid. And one can see his reasons. It *isn't* clear just what it is to be a "real potential". Martin takes the term at face value, ignoring the epistemic confusion brought on by it. "Disposition" is unobservable in principle. What we see are manifestations of dispositions. Not only are we dealing in unobservables, but perhaps the worst kind.

Look at the problem this way. We might ask what it is that makes a chair "real". What is the answer - that it's "there"? Well, the same concepts ought to apply to a potential, it would seem, but the concept does not avail itself to such workings. While one may be tempted to ask what is "unreal" about the readiness of salt to dissolve, a person like Armstrong might claim that unlike "chair", "potential" by its very concept or nature is an abstract notion. There just are no "potentials" in the room, in any real sense. There is a chair (some matter), sure, but no "potentials", not in any non-abstract way. *That we can conceive of potentials is irrelevant*. They aren't a necessary part of the causal story (from Armstrong's point of view. Conversely, if we accept Martin's assertion of identity of the categorical and dispositional, we cannot do without potentials.).

We have found the hinge on which this argument turns, so to speak. For some, the notion of a real potential will be quite clear and indeed the foundation of ontology. For others, "real potential" will remain mind-dependent - epistemic rather than ontologic.

We also find in this corner of the debate (the corner of abstract/concrete laws and such) a place where Martin's theory is hard to grasp for many. Martin has no "Laws of Nature" over and above dispositional interactions. The "laws" we are used to are built up out of dispositional interactions. Thus, all things with "mass" disposition lines affect each other gravitationally. The "law of gravity" is then the "law of behaviour of things with the property of mass". Martin has no need for further laws above what might be called "dispositional laws".[13] This might seem a banal point, but the less confusion we generate in our wake, the better.

Perhaps more important than our grasp of Armstrong's ontology is our familiarity with his clear-cut separation of the ontological and the epistemological. This is an admirable thing and warrants more attention than it seems to have received. Armstrong's anti-abstract stance is reminiscent of Sir Karl R. Popper's falsification criterion for the scientific. Popper's demarcation of science from non-science may or may not be acceptable, but at the very least it provided a) a *clear* definition , and b) something to work *from* (if we do indeed reject "falsificationism"). That is, we have been bequeathed grounds from which to work. Armstrong gives us similar things: we have a definite border for the acceptable, and with that comes characterizable philosophizing about ontology (whether the results are acceptable or not). I have a genuine soft-spot for Armstrong's approach, though I am a disciple of Martin's. I think Martin's case of element X is decisive - it shows Armstrong's ontology to be futile. And yet Armstrong's *approach* seems intuitively correct to me. This seeming paradox leads me to wonder about the whole enterprise of ontology. We have on one hand a methodology we like - talk about things that are in the world if you want to talk ontology - and on the other hand, a seemingly failed ontology crafted upon just that foundation. How could things go so wrong?

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[13]D.H. Mellor has put forward a dispositional view which includes laws of nature as well. However, I think he merely wants to call dispositional interactions the "laws". A view containing laws as very separate from dispositions would be strange indeed. Perhaps the laws control the dispositions? But then we need laws to control the laws. This regress is as unnecessary as it is silly, and Mellor must surely know this.

On the face of it, Armstrong's anti-abstract intuition seems like a very reasonable stance. If you want to develop a theory about how the universe works, it seems fair to suggest that you keep your discussion on things that are indeed in the universe. This stance makes perfect sense, but things cannot quite end there, of course. What Armstrong is explicitly against are abstract objects. Is this necessarily what we have to believe? It seems so clear on an intuitive level what abstract objects are (something comprehensible but perhaps not realizable in any concrete form?), but when one really tries to spell it out, one winds up saying silly things (or at least, I do). This is perhaps the problem - Armstrong also has difficulty with the abstract, and this generates within him a sort of skepticism with regard to it. I have tremendous sympathy for Armstrong's commitments, and even though I think the previously mentioned case damages Armstrong's particular ontology beyond repair, I think the commitments Armstrong puts on the table are admirable enough that while we may decide against his theory, we ought to take a look at others from his point of view. It is only fair that we have approached Martin's theory from Armstrong's perspective.

What are we to say of dispositions in response to Armstrong's challenges (of abstraction at best and nonsense at worst)? In the first place, we must decide whether dispositions are indeed abstract, that is, whether they fall hither or yon under Armstrong's demarcation criterion in the first place. Spatio-temporality seems to be the "standard" of abstraction. Unfortunately, it is not all that clear what a non-spatio-temporal entity might be like, so the standard is itself obscure. Proceeding via example is no real help - suggesting that things like tables are indeed spatiotemporal does not in any way rule out that dispositions are also spatiotemporal. Likewise, suggesting that God is not spatiotemporal will not prove that dispositions are also not spatiotemporal. Some other approach is clearly needed.

We first need a better definition of "abstract" if Armstrong-style metaphysical commitments are to carry weight. One such might be K. Campbell's offering, his suggestion being that the abstract is "what is got before the mind by an act of abstraction".[14] This apparently vacuous definition is actually worth some attention. I think Campbell is standing precariously between Martin and Armstrong. I believe Martin's blending of epistemology and ontology comes out something like this: if we can clearly conceive of something, and the something seems to fit into a picture of the world, thinking it a part of the world is a reasonable step (though not a logically necessary step - that we can conceive of pink elephants is no indicator that they exist in the external world. And yet, it may indeed be an indicator that pinkness and elephants DO exist in the external world.). Conception is a sufficiency criterion, we might say. Armstrong is a bit tighter, a bit more hard-headed in his realism. That we can conceive of something means very little to Armstrong in terms of the ontological significance of that particular concept. Perhaps Campbell's "act of abstraction" allows us just enough room to maneuver - perhaps we need not suggest that dispositions are nonspatio-temporal merely because they are got before the mind by "abstraction". Under Campbell's definition, imagined chairs are abstract, but chairs are not, and as we are able to imagine dispositions as the underlying feature of all that there is, we might be entitled to think they are indeed par of the world. This may strike some as word-play, but our further philosophizing depends very much on clearing some of this stuff up.

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[14] Campbell, p.351

How much farther from Campbell's definition do we need to go? Clearly, the no-nonsense Armstrongian approach will keep us "in the universe" (in the realm of space and time), but it isn't clear to me that allowing abstract objects (under Campbell's definition) is going to put us "out of the universe" (take that, skeptical dogs!). I tend to think that this slightly less technical definition gets a bit more mileage than the standard, and helps us along a bit with our thinking. Given Campbell's definition we might just slip Armstrong's noose and find ourselves able to develop an "abstract" ontology which does not immediately fall victim to anti-realism. The anti-realist gains more purchase on abstract entities like laws of nature, or dispositions, than can be gained on the utterly concrete, like tables and chairs. Thus, to ward off the anti-realist, we must, like Armstrong, remain firmly "in the universe", but unlike Armstrong, we must allow some sort of "less concrete" entity into the picture, be it abstract laws of nature or dispositions.

Incidentally, I assume that Martin's talk of "disposition-lines" is a move in "Armstrong's" direction - lending more concrete spatio-temporality to dispositions by the imagining of an infinite web of real potentials in space-time. This seems more like a conceptual scheme than anything else - a proposal for the understanding of an "infinite web of interaction potentials". "Disposition-lines" are a way of thinking about dispositions. This brings us to an interesting thought-junction. *Ought* we propose some sort of anti-realism with regard to dispositions? I think not. This would make for an exciting albeit rather strange approach. I think beginning an ontological project with something best regarded as a conceptual tool rather than as "real" is a rather large step in the wrong direction. The idea of ontology is to give a theory of what there is, not merely a theory outlining one possible way to conceive of what there is (which, to reiterate, is what Armstrong would be justified in thinking Martin has done).

We generate ways of talking about the world which we hope correspond to the world, and Armstrong, slightly more skeptical of our ability to keep ontology and epistemology clearly delineated, is not sure that we can expect good correspondence unless we monitor ourselves at every step, always on the lookout for the abstracta which might be our downfall. Martin on the other hand is happy to talk about the dispositional, a concept which seems relatively easy to grasp clumsily (the concept of "potential"), but more or less ignores the epistemically upsetting character of dispositions. That is, he ignores the possibility that dispositions might be nothing more than a good way of talking about the world (without necessarily corresponding to any element of "Reality").[15] This possibility, which might properly be called dispositional anti-realism, seems like a contender to people like Armstrong. Now, Armstrong is no anti-realist, but the possibility that Martin's work might be cast in an anti-realist light (over Martin's dead body) is enough to make Armstrong think twice. And it should make us all think twice. After all, if dispositional anti-realism is possibly correct, the dispositional realist cannot expect to easily prove that what he is talking about is part of reality. (Martin would suggest that he doesn't have to prove that - it's just not part of the game).

This is skeptical talk, sure enough. We must decide how much skepticism is the right amount for the ontologically minded philosopher. Armstrong's more skeptical position seems to make sense, yet it also leads to untenable metaphysics. Martin's

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[15] Martin argues that one cannot give a coherent story about the world around us without using something akin to potentials. Even if this is correct, which many argue, we still owe oursleves the clearest idea possible about them.

position is more open-minded about what kinds of things to think of as "real", but because of this, the anti-realist gets a foothold in Martin's work that is unavailable in Armstrong's.

If we were to suggest that the anti-realist cannot gain as much purchase in Armstrong's world as in Martin's, we may be reminded once more of Schopenhauer. Indeed, it may seem that Armstrong's skeptical stance puts him well within the walls of the fortress, and prevents him from sallying forth. Martin's tolerances are perhaps not as tight as Armstrong's, but at least he has room to maneuver within the conceptual framework he provides. My sympathy and intuition go with Armstrong, but in the end, a stance more like Martin's, a stance more open to the abstract (still under Campbell's definition - Martin would never claim that dispositions are not spatio-temporal!), *a less skeptical stance*, seems to be necessary.

Martin's Theory Proper

If we grant that Martin's theory is promising, we need to look into it for details we have not yet discussed. We can call Martin a property theorist whose theory has one substance. That substance is space-time. Everything else, all the tables, people, dogs, the Aurora Borealis - everything else is to be thought of as property events in space-time. This is at first an anti-intuitive view, but it certainly has its charm as well.

Physicists tell us that electrons have such properties as mass, charge and quantum spin. However, electrons do not have such properties as structure or radius. This seems utterly baffling if we are committed to a view of the universe in which we expect to chop tables down to little hard atoms which cannot be chopped further but which still exhibit familiar properties (like having a size). Such "intuitive" thoughts become less intuitive when we are forced to give an account of what such atoms might be like. Form without structure seems like a difficult proposition, and structure indicates an ability to be further broken apart. Thus, assuming that there is some final substance which shares a lot of properties with the medium-sized day-to-day things we are used to is probably a bad thing to do. It will be difficult to tell a story of about a little ball which has mass and size but cannot be broken into anything smaller. Equally difficult would be a story about a little "ball" which has mass but no size. And this is just what an electron is. Assuming that "things" break down into littler "things" is not going to work. Assuming that "things" break down into properties is a better approach, and more a more natural fit with the science we believe.

If we embrace the notion of property being of the fundamental order, then the fact that an electron occupies no measurable space is a bit less puzzling. After all, if an electron is merely compresent charge, mass, and spin, we ought not expect it to be anything else. Taking properties as the base unit in ontology actually clears up some conceptual problems.

Emergence

Non-primitive properties (like whiteness, which depends on some photons being around. Compare with charge - charge "just is") are going to be cast as "emergent" (that is, they are not reducible merely to some concatenation of "lower level" properties). Primitive properties, like charge, are not emergent. (Or perhaps they ought to be considered the *most* emergent... emerging from the fabric of space-time itself.)

If this sounds like a strange approach, think for a moment on what an emergenceless metaphysics would be like. We might, for example, be constricted to believing that all properties of complex entities are somehow "extracted" from the matter of which those entities are composed (after all, we don't want properties "popping" into being if we are against emergence!). Martin has called this the "pipeline" view of causality. Every effect has its cause, and for those causes (the Aristotelian Efficient Cause), we would have to look into the quark in each case. While it is surely acceptable to suggest that the properties of, say, my hand, are properties of matter, and all matter made of quarks, it may seem odd to suggest that all the properties of my hand are properties of quarks. What does this amount to? It can be taken two ways, one foolish, the other serious. The foolish way is to read literally, and think that a non-emergence metaphysician is constrained to believing that quarks are four inches across and brownish pink. Rather, what the non-emergence metaphysician must be after is a view that hands come about by sticking molecules together, and that thus, whatever properties hands have, certain groupings of molecules also have. Molecules are made from atoms, and atoms from quarks, so everything reduces down to properties of quarks. But this explanation does not go far enough.

The question which needs focusing is "What is the story of how do hands come by the properties they do?" With this in mind, we see that the non-emergence campaigner must answer in terms of certain groups of matter having some characteristics (like skin, let's say) and other groups other characteristics (like fatty tissue). We need to tell a non-emergence story of how this can be.

We can begin the explanation by putting quarks together to make a proton, and then work our way up. If we can give all of the proton's properties in terms of properties of quarks, we might be able to go right up through atoms to molecules to proteins to hands. However, I am not sure that we can do this with a clear conscience. One property of protons is that they have a dipole moment, due to the configuration of the charges in the quarks. (A set of charges revolving about an axis will tend to orient itself in a magnetic field, due to the magnetic field generated by the moving charges.) Quarks themselves have no dipole moment. Is the dipole moment of protons to be constructed as a property of quarks in a certain arrangement? The answer is yes and no. We can, with a straight face, suggest that because protons are nothing but quarks, then properties of protons are properties of groups of quarks. And here we might find the "no" part of our answer. The grouping seems to be of utmost importance, metaphysically speaking. This is not bad, per se, but it isn't clear how we can say that no "new" property has been found; that the property of dipole moment is somehow in *each* quark.

Consider what we will say about other properties of the proton. Its mass is the cumulative mass of its constituent quarks. No "new" property there. Charge of the proton? Cumulative charge of the quarks. Again, nothing new. Yet when we consider dipole moment, we find a property never exhibited by the constituents of the proton (when they are alone, in an "unbound" state) and we are therefore at a loss when it comes to describing the relation of this property (of the whole) to the constituents (of the whole), other than to say that when they get together (as a whole), they exhibit the property. (And this I take to be something like Martin's view. His suggestion is that the property of dipole moment *is* a new property, not to be found in any particular quark, but that it is indeed a property of quarks nonetheless. Let us unravel this, for it at first appears to be nonsense. Remember that Martin is committed to the identity of disposition and "property" at the base level. Thus Martin is forced to use the two words rather interchangeably, and this is not to his advantage when dealing with the uninitiated. Martin would prefer to say that quarks carry the disposition (and thus the "property") for dipole moment, but they do not themselves (or rather, *alone*) manifest dipole moment. The property is manifested only by groups of quarks. Thus Martin's view can seem confusing, seeming to claim both that something is and is not the case. In reality, we just need to keep crisp the disposition/manifestation demarcation. This is a subtle view, and I think it will take one farther than any other. Unfortunately, it is also very confusing if words like "property" are not used with utmost care. It is not a novice-friendly theory.)

It is critical to understand that we are *not* missing the *reductive explanation* for dipole moment: we know why the property occurs. What we are missing is a way to extract the property from the individual quarks, and this is exactly what is required by the non-emergence campaign.[16]

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[16] In issues like this, we may need to decide a heretofore largely ignored issue in metaphysics: is there a difference between a zero-valued property and an absence of property? Yuri Balashov argues convincingly that there is a difference. The relevance to our debate is that if we view quarks as having a dipole moment that measures zero, we can, in some sense suggest that dipole moment is a property of quarks. However, I think Balashov's paper shows that quarks are rightly viewed as not having the

The proton's dipole moment is best seen as a "new" property (that is, a property not demonstrated by the quarks constitutive of the proton in question). Can it be maintained by the non-emergence metaphysician that the dipole moment of a proton is a "new" property and yet still a property of individual quarks? The answer must be "No." on the simple grounds that such a belief makes no sense. We cannot rationally attribute a property to an entity which never exhibits the property and which we have good reason to think *cannot* exhibit it (whereas the dispositional emergentist can rationally attribute the *disposition* to form a bound state with all its associated properties). The non-emergence metaphysician must then accept that a new property has been found, and must explain this. However, if the property is "new" and is to be construed as a property of *groups* of quarks (as it must be, given the arguments presented above), *then we are talking about emergence*. What does this amount to? The proton's properties are *not* anything over and above the properties of quarks in a bound state (emergence is not a "magical" doctrine, where properties "pop out of nowhere"). The "new" property of "dipole moment" *is* identical with some property of bound quarks BUT it is also a property that the quarks *themselves* do not possess, and thus the epithet "Emergent Property" is applicable. This is all "emergence" need mean.

The foregoing is my opinion, and perhaps mine alone. As parenthetically mentioned above, Martin has advised me that he feels that we are better off suggesting that dipole moment *is* a property of quarks, and that the property "emerges" when the quarks are brought together in a bound state. As "dipole moment" is a disposition

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property at all, as quarks do not break down into further entities which do have dipole moments. There is no reason to suggest that quarks have a dipole moment, and Occam's Razor is rightly applied here. And generated by the grouping of the quarks, I can see the philosophical value of such thinking, but I think it generates more confusion than the view presented above. That is to say, I would prefer to say that dipole moment is in fact not a property of quarks, but that it emerges when quarks are bound. I am aware that this violates logical stricture in that disposition and property are logically identical (and therefore it is self-contradictory to say that quarks have a disposition for dipole moment but not the property itself.) but since not everyone is willing to talk disposition/manifestation talk, it may be easier in the long run to loosen things a bit, if only as a sort of temporary teaching guide.

I understand that a theory of emergence similar to the one I am propounding may be problematic in that we might be asked to explain where the property of dipole moment "comes from", if it isn't a property of quarks (whereas Martin does not have to explain this. Philosophically, Martin's talk has more power.). I think the best answer is that it emerges at the same time the quarks are bound, and that it is a property *of the group* which is manifested because of the dispositions of the quarks. We have the reductive explanation for why the property is found with the particular group, and nothing more is required.

No matter which version of emergence is accepted (and I think one can distill the same essence from either), it can be seen that an emergenceless metaphysics will be a difficult and, as Martin says, "exciting and daring ontology."

There is another case in physics which may end argument over whether emergence is a necessary addition to any theory. The oscillation of neutrinos between electron, mu, and tau forms may be indicative that a non-emergence metaphysic is wrong-

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of course, to suggest that the proton's exhibiting of dipole moment is indicative of quarks having the headed. It seems that the properties of any given neutrino can change, and the change is not due to a rearrangement of anything internal, as there is nothing "inside" a neutrino to rearrange. Simply put, if the neutrino is structureless, an argument from concatenation is simply not available. What story could be told? If there is no structure to the entity involved, then "concatenation" is out of the question when discussing the properties of the lone entity, and the upshot of this is that the non-emergence metaphysician has no grounds from which to argue. If something can manifest different properties without any internal rearrangement, then a reductive story without emergence will be unable to grip the situation.

This case is still at the hypothetical stage, as we still know very little about neutrinos. For the case to be decisive, the oscillation of properties needs to be truly intrinsic, and that means we must rule out the possibility that neutrinos have only one "set" of properties, the manifestations of which we are confused about. We need for some neutrino to be "caught in the act" of manifesting differing properties at different times, under experimental conditions known to be the same in both cases, and we have to know that nothing about the neutrino changed except its dispositions for certain manifestations. That is, we need to know that neutrinos have no interchangeable bits and pieces which can affect the behaviour of the whole. No concrete picture can be devised to describe such a situation, and thus reduction will fail. (This is analogous to the explanation of an electron's quantum spin. The fact is, we don't know what the electron is doing, we only know that it is a magnetic effect. This case alone provides difficult chewing for someone who would argue against property emergence. Electrons are not made up of quarks, or of

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property is merely begging the question.

anything else, as far as we know. How is it that they manage a magnetic effect? We call it "spin" because if an electron did really spin, it would set up a dipole if it took up any space (which it doesn't in the first place). The fact is, we don't know what quantum spin is, and don't have a reductive story for it.)

Neutrino oscillation might seem a longshot case in that it will be years before anything decisive can be said, and even then, as Popper warned us, we can't be totally sure (everything is falsifiable). However, if reasonably conclusive evidence is found (and some would argue that it has been, of course), the non-emergence metaphysicians will have to concede that properties can arise which are not due to concatenations of the constituents of the entities in question.

Once we embrace an ontology of properties without substance, we can open our minds to the possibility that while concatenation of "fundamental" property carriers *is* a way to generate "new" properties, it is not the case that those properties must somehow reside in the fundamental units (or, with Martin's view, that anything above the dispositions must reside in the fundamental units). In looking at examples from physics, we see problems with the concepts required for the pipeline view.

Given the above considerations, emergence is not as strange as it first sounds. It is the necessary upshot of a property-founded ontology, and does not imply a non-reductive metaphysic. The new properties generated are just part of the manifestation of the reciprocal dispositional partners in question (and it just so happens that the manifestation has its own special new dispositions).

Causation

Martin's depth of development can be found in his burgeoning theory of causality in general. The dispositional view with its mutual manifestation partners does away with age-old epistemic concerns about causation. We need no longer be concerned over the seeming gap in time between a cause and an effect, nor do we need to worry about whether or not they are separable events (if there is no gap in time). That is, manifestation (of whatever sort - we can be talking about the manifest property of rolling a can of beer down a ramp or of an electron being "captured" by a fluoride ion.) occurs exactly when the reciprocal partners are brought together - that's what manifestation is. Any other effects can be seen as just that - effects in a causal chain which was initiated by a single manifestation event.

"Cause and effect" as such, become outmoded (Armstrong's Razor again!). We need only talk in terms of dispositions and manifestations. Thus the "cause" of a glass breaking is that the relevant mutual manifestation partners were brought together. The glass manifests its fragility exactly when the partners interact. The *entire* event is of course not instantaneous - the other dispositional properties of the glass make it such that the event takes some time.

Even such things as so-called action-at-a-distance are untroubling, as no pre-established physical parameters for causal interaction have been set. Manifestation need not occur in a proximity-dependent fashion. This may be of critical importance in the quantum realm, which is where I would now like to turn.

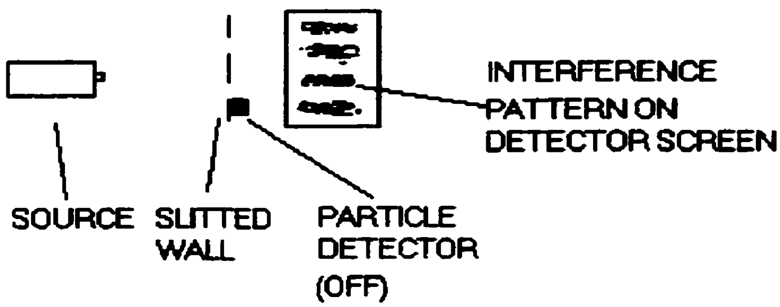
Part 3 The Fitting

It is my intention in this section of the paper to lay out some experiments from physics in dispositional form. My hope is that even in the most ontologically convoluted form (which we may or may not embrace), quantum mechanics conundrums can be dealt with by a pre-established metaphysical system of sufficient strength. In order for a metaphysical approach to be honest, it should deal with the toughest material available. If "the truth" turns out to be less exotic than has been suggested, well, all the better. Thus, as we proceed, I shall attempt to give more than one explanation, more than one interpretation of results, not necessarily fighting for what I deem to be the correctness of any particular one, but to show the ontological map, as it were.

The Double Slit

There is a famous experiment (or rather group of experiments) known as the double-slit, or interference experiment, which goes as follows. One might build an apparatus such as the one in figure 1. It consists of a source of "particles", a wall with two closeable slits, and a detector of some sort on the far side. It might be done with a lightbulb, the "particles" in question being photons, a cardboard wall, and a photographic plate. It can be done with electrons easily, and also with atoms, like silver, for instance. The apparatus will vary somewhat, but the principle and the results are the same in the relevant ways.

Figure 1.



What happens is that if one "shines" the source at the wall, with both slits open, an interference pattern develops on the detector at the far end. This is indicative of a wave phenomena (the waves diffract at each slit, and interfere on the opposite side of the source - canceling each other out in some areas (nodes), doubling the amplitude in others (antinodes).

This is remarkable. Immediately we begin to speculate about the nature of the "particles" in question. Are they somehow also waves?[17] But enough of this. The interesting part of the experiment is also the mind boggling part. If the source is "turned down", that is, if it emits only a few particles per hour, say, the interference pattern still appears. It seems as though each atom knows where the others have gone; that the "diffraction waves" still exist somehow, OR that each "particle" goes through both holes, diffracting and interfering with itself!

To clear things up, we can put a detector in the slits to find out which hole the particle goes through. (Rather, turn on a detector that has so far been dormant - we wouldn't want to drastically change the experimental arrangement by putting in new "physical" components - we must change the system as little as possible.) Indeed, as we intuitively suspect, the atoms (electrons, photons) do go through only one hole. We can find them if we turn the detector on. But if we do this, the interference pattern goes away! See figure 2 on the following page.

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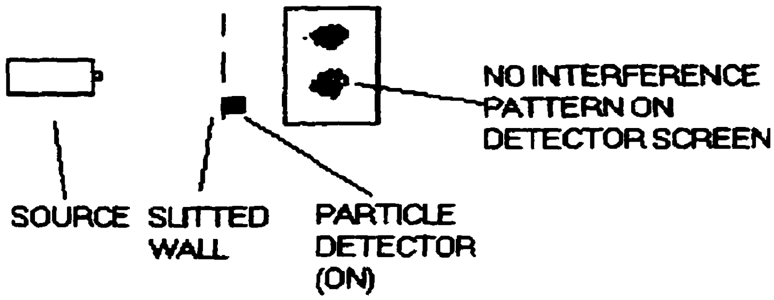
[17] Of course, DeBroglie is way ahead of us on this one, having already proved that all masses have a wavelength. In some sense, the rest of this paper can be viewed as attempting to sort out what DeBroglie found. More will be said as we proceed.

Figure 2. The apparatus with particle detector in slits (turned on).



This experiment led physicists and philosophers into a muddle. Roughly speaking, if you look for a particle, you find one, and if you don't, you get a wave. Very roughly speaking, when one observes the atoms, one somehow seemingly removes the wavey nature.

The Copenhagen Interpretation

Enter the Copenhagen Interpretation of the Schrodinger Equation. We are given by quantum mechanics a function (satisfying the Schrodinger Equation) which seems to indicate the *probability* of finding a particle in any given place (when the equation is solved for position), and nothing more. But when we look, or "observe" a system, we find particles rather than probabilities. "Reality" occurs, so to speak, when we observe. Immediately, two possibilities spring to mind. One is that the Schrodinger equation does not fully describe the world (that QM is somehow incomplete). The second possibility is that the Schrodinger equation describes the world before measurement occurs. The Copenhagen Interpretation embraces the latter belief. (The former idea was held on to by realists like Einstein, who never accepted the Copenhagen Interpretation. Unfortunately, Einstein and Bohr were never to find a middle ground. Perhaps we can.)

The business of finding particles only when we look is construed as "the collapse of the wave function" (the idea is known as the von Neumann postulate); we literally create "reality" when we stick our noses in. Before we observe a quantum system as simple as an electron in a box (officially, an electron in a potential well - some or other environment which "traps" the electron by offering a place of low potential energy relative to neighboring places - thus, a "box"), the electron's existence (ontologic) is thought to be described *fully* in terms of probability. In some sense, the electron is not "there" until we look for it, and when we do look for it, it sort of "pops" into existence. "The Observer" is born. "Reality" occurs as we take measurements - until then, only probability exists, according to the doctrine.

Such thinking is obviously a radical departure from previous "scientific" pictures, starting perhaps with Democritus' ontology of atomic substances. And of course, this departure is the point of contention. There are two main camps of opponents here, we might call one the ontologic camp and the other the epistemic. The ontologic camp might argue that such a radical departure from "clarity" is uncalled for and ought not be accepted - that we should direct our efforts at developing a less bizarre or abstract view of the universe. Occam's Razor might be appealed to, with the claim being that we should stick to the simple if possible. The downfall of this style of argument is that a "scientifically minded" person would require *evidence* prior to making any declarations about unraveling the mysteries of nature. The argument, "I'm *really sure* nature isn't full of weird abstract stuff." just won't do, and there is no other argument available.[18] The grounds supplied for doubting rely on something akin to an induction - everything we've seen has certain properties or structure, so everything must have certain properties or structure (even when we're not looking at it!). The fallacy of such thinking need not be pointed out. Hard-core particle-realists will of course protest that I have understated their case. I do not believe I have. We have no right to tell the universe how it must be.

The second camp offers a slightly different approach, more epistemologically oriented. A philosopher can point her finger at this stage, and say "The Copenhagen Interpretation is just skepticism with regard to pre-measurement reality!", and many have. Indeed, this style of criticism may carry more philosophic weight than our ontological concern (which is based on "the world we're used to"; a veiled appeal to Occam.).

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[18] There may be an argument which utilizes Occam's razor, but we have to decide whether the Copenhagen Interpretaion or some other interpretaion is "simpler" - and of course "simple" is open to defining as well. But theis is a serious issue which will be dealt with in the text.

Does the Copenhagen Interpretation fall victim to our anti-skeptical arguments? I tend to think not, because there is in fact ground for doubt (other than the puzzling experiments etc.), and it runs like this. Ordinarily, we are used to thinking of physics equations as giving us the full description of reality. For instance, Newton's law F=ma requires that a force be equal to a mass multiplied by an acceleration, and that's just what a force *is*. And if there are things called forces, and they are part of the world around us (that is, if our equation is telling us something about the world) then the Schrodinger equation should tell us what is going on in the world because it does the same sorts of things other equations do; it *represents the world* just as the other equations do. With this in mind, we have reason to think that "reality" is going to be something unorthodox in this situation - after all, we have an unorthodox equation (compared to Newton's equations, that is).

On top of all this fancy philosophizing, the double slit seemingly vindicates the Copenhagen sort of thinking. "Particles" are found only when "The Observer" sticks his beak in - the rest of the time, we get wave behaviour, presumably because the electron exists in a strange wavey state; a state described by the Schrodinger equation.

The Copenhagen Interpretation makes *some* sense, and to be fair to Bohr, von Neumann, and others, no other theory seemed to make more sense at the time this was all being wrangled with. But this Copenhagen thinking does give rise to certain "reality paradoxes", the most famous being "Schrodinger's Cat"[19], which goes like this. We put a cat in a container (like a cardboard box) with a device, the activation of which depends on the spontaneous decay of a certain atom. The function of the device is to kill the cat. If

[19] The paradox was proposed by Schrodinger, unhappy with the Copenhagen ontology.

the atom decays, poison is released, and if not, not. The paradox is that until we observe the cat, it seems to exist in a strange state of being half-alive and half-dead: the mathematics of quantum mechanics does not allow us to say *anything* about the cat except that it exists in a funny state called a superposition. It in a state of superposition of being alive and dead. Neither alive nor dead, nor neither, nor both, as it has sometimes been described.[20]

We can also describe the wave-aspect (result) of the double slit experiment as a superposition (unless we detect the particles - "Observe" them). The "particles" in question are in a superposition of going through both holes. They actually gó through neither. And yet they do. Get it? Nor do I. Nor does anybody. Unfortunately, nobody knows how to describe a superposition any better than that. In the words of Cambridge physicist D. Lindley, discussing the notion of quantum spin, "It's not so much that we really know what we mean when we say an electron is both up and down but at the same time neither really up nor down, it's just that we've grown a little familiar with the idea, and since we don't have much of an idea what an electron looks like in the first place, it's perhaps a little easier to accept without protest that it can inhabit a weird and indescribable state. But when we try to translate any half-formed idea of what we mean by a superposition into the world of cats... then we run into a wall."[21]

It seems that many physicists can live with such a wall. They are interested in explanation and prediction, and Quantum Mechanics works very well for that; better, in fact, than any other theory ever has. For philosophical purposes, it is worthwhile to think

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[20] And this is obviously a problem. Schrodinger came up with this thought experiment as a means of showing the oddity of "The Observer" in metaphysical terms. He was unhappy with cats existing in indescribable states.

about this a bit more. There is a funny gap in explanation here... the Copenhagen Interpretation is giving us an admittedly weird ontology of half-dead half-alive cats, and suggesting that such things are no stranger than good old wave-particle duality, whatever *that* is. We ought not accept it.[22]

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[21] Lindley, P.169

[22] This "summation" of the Copenhagen school sounds tongue-in-cheek, but it is fairly accurate. Cutnell and Johnson's Physics tells us in typical orthodox style that "The DeBroglie equation for particle wavelength provides no hint as to what kind of wave is associated with a particle..." and goes on to tell us that the double slit shows us that "...particle waves are waves of probability." with no discussion as to what the underlying reality might be. This is typical of the hard-core physicist's "Who cares what it *means*?" attitude, and spawns confusion in the ranks of those who want to come to grips with the ontological situation.

Superposition and Dispositions

Superposition is a technical notion which comes to us directly from mathematics. The solutions to a second order linear differential equation (Like the Schrodinger equation) can be added together to form another solution. Thus, the general solution is $Sa_i\Psi_i$. It is this fact which the Copenhagen Interpretation tries to incorporate into its ontology, and the result seems to be as Schrodinger implies; that premeasurement systems exist in a strange state described mathematically but difficult to conceive of. Nor is this merely abstract mathematical philosophy - we find that atoms exhibit the behaviour of "hybridization", forming orbitals which are effectively the sum of different solutions to the Schrodinger equation of any particular energy level (combining the so-called S orbital with the three P orbitals to form four SP_3 orbitals which in size and shape are a combination of the two, for example). Thus, superposition is a well-grounded concept in the atomic world, and any attempt to explain quantum mechanics without reckoning superposition would be farcical.

Superposition is a concept which seems to apply quite literally in the quantum world. But how well can we understand it? In the case of hybridization, we find that atoms like carbon, for example, bond tetrahedrally, and this is only possible if the s and p orbitals (separate solutions to the Schrodinger equation) "combine". That this is a mathematically acceptable situation is more than pure good fortune - the entire concept of covalent bonding hinges on the ability of atoms to utilize separate and combined solutions to the Shrodinger equation. (Seen from a certain perspective, it is as though nature had no choice but to make bound electrons follow such rules.)

It is important to point out for future reference that the hybridization occurs due to physical circumstance. Hybridization is an available mode of being for many atoms, and they hybridize when physical interactions provide reasons for them to do so. A tetrahedral bonding arrangement allows electron pairs to gain as much distance from one another as possible - maximally relieving the physical stress of the mutually repulsive electromagnetic forces of the paired electrons. On the other hand, we can force atoms to "unhybridize" if we wish. For example, we suppose that a methane molecule (tetrahedral in shape) under nucleophilic attack at some stage must "invert" itself, allowing the nucleophile to bond while a hydrogen atom is ejected from the other side of the structure. The "transition state" as it is known, is a planar sp_2 hybridization, whereas both the initial and final state of the central atom is the tetrahedral sp_3. Thus we see that the hybrid state we find an atom in is relative to its physical situation. The mathematics describes a sort of abstract availability of electron configurations, but "reality" is determined by physical parameters. The question now becomes one of determining those physical parameters for different systems.

Let us go back and talk about the double slit, but this time, in terms of dispositions and manifestations. The first thing to do is redescribe in general what is happening. The apparatus is seen as offering reciprocal disposition partners. We are finding two different manifestations - wave and particle, to be precise. The wavey manifestation occurs when we have a source, two slits, a particle detector of some sort (switched off), and a screen:

the particulate manifestation occurs when we turn on the particle detector in one or both of the slits.[23]

Immediately, we need to slightly broaden our concept of a disposition. Atoms, photons, electrons, etc. have dispositions, the manifestation of which depends on the partner provided. They have readinesses for more than one manifestation, and what we see (which of the possible manifestations) will thus depend on what sort of apparatus we use. Thus, when we use a particle detector, we get a particle-manifestation (of course!) and likewise with no particle detector (no particle manifestation). The slits and screen are wave-oriented dispositional partners for the "particles", one might say. (One might also say that the particle detectors are particle-oriented partners for the "waves" in question...) This is not as bizarre as it sounds. A lump of sugar dissolves in water; it turns brown over flame. Is sugar thus some dual-natured demonic thing? No. Or yes. What matters is that it simply manifests differently with different reciprocal partners. That we find wave and particle duality at the quantum level is perhaps unexpected, but that's just our tough luck - it's not necessarily the strangest thing imaginable. We are merely used to certain properties excluding others - if a baseball is hard when it hits my baseball glove, it probably will not be soft when it hits my head. However, wave properties and particulate properties do not necessarily (in the logical sense) exclude each other. A baseball cannot be both hard and soft *at the same time,* but soaked in water for long enough, we no doubt could procure a soft baseball. Thus what seem like exclusive properties can be manifested

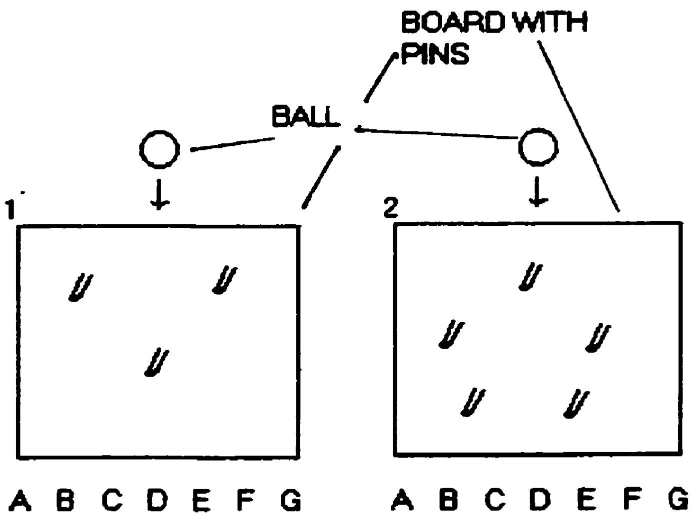
[23] In fact, to "break down" the superposition, the slightest "tap" will do - we don't even need a "particle detector". Adjusting internal quantum states via microwave radiation will also do the trick. See Buchanon's article in New Scientist, 6 March, 1999, no.2176

by a single entity, but merely at different times, and with different reciprocal partners. Wave now, particle later, wave again after that, all depending on the partnership scenarios.

Karl Popper suggested long ago that the mystery of the double slit and other experiments is softened by an analysis in terms of experimental arrangements.[24] Popper tells us to imagine dropping a ball down a board with pins sticking out - the ball's path is determined by the pins and the initial conditions (the ball's velocity vector and initial position). We might measure the frequency of the ball landing in any particular area beneath the pin board. Move the pins - a different set of frequencies in the landing zones will occur. See diagram 3 on the next page. But even experimental arrangement goes only a very little way of helping to UNDERSTAND what is going on in the double slit. We might begin to accept that there may be a reason other than "The Observer" which explains why the double slit yields the results it does, but we are not given any *particular* ontological grounds for the acceptance of any *particular* idea. In other words, we might accept Popper's anti-Copenhagen view and still be left questioning what it is about any particular experimental arrangement that gives us the results it does. And Popper is no help here because he lacks an ontological base from which to offer explanations. Martin's theory is a handy tool at this point.

[24] Popper, P.153

Diagram 3. Popper's "Experimental Arrangement Argument"



The frequency of landing in any particular zone A-G is determined by the pins, as shown in this table of landing frequencies.

Landing Frequencies in 100 drops

Landing Zone	A	B	C	D	E	F	G
Board 1	19	27	3	2	5	24	20
Board 2	10	3	5	72	4	1	5

Even so roughly laid out, it seems that the dispositional approach will get us relatively farther down the causal chains in question than previous approaches. We have a means of accepting duality (which at this stage need only mean differing behaviours under differing conditions). But we have yet to deal with a few slight technicalities...

The last thing to clear up is what could be happening when our particle source is turned to low intensity. Why do the particles *still* give an interference pattern when they seemingly have nothing to interfere with (even if they do somehow "diffract")[25]? Martin has postulated something called "flutter". It is suggested that the particle in question has an intrinsic variation in disposition, which manifests itself as the particle passes through the slit in the wall. The subsequent vector of the particle depends on which "flut" of the "flutter" as Martin might say. (This will be constructed in Q.M. talk as a "hidden variable".)

The postulation of flutter in the double slit experiment is ad hoc, and Martin admits this with candor. However, the intrinsic evil of an ad hoc element can be somewhat warded off by related "epistemic" concerns. What I mean is this. Martin is a realist trying to give a realist theory. As such, when shown the apparent wave-particle duality of the double-slit situation, he is not comfortable suggesting merely that the dispositions in question are complex; that each "particle" in question also has a wavey disposition which is sometimes manifested. This type of answer leaves out a good description of the

[25] This is perhaps a specific form of a worry one should already be forming - how do we get wave-behaviour at all if we are to maintain a full particle-realist conception of the universe? Outright acceptance of very real wave-particle duality is on the horizon, and this is fully acceptable to the disposition theorist who has no preconceptions about the reality of "particles" - but this is still a relatively confusing ontology. So far we have the Copenhagen Interpretation being "underwritten" by disposition theory, utilizing a rather blurry notion of exactly what we are dealing with when we say "particle". I feel that a more "realist" picture ought to be sought out, wherein we can talk of "real" particles, or at least "real entities" if not particles, and the Copenhagen Interpretation does not allow for this, pre-Observation.

wave/particle entity before the slits - leaves out a particle-realist's conception of "what was there before we measured". And if such a realist description could be given more or less within the confines of the Copenhagen Interpretation, everything would work out. But no one has been able to develop such a description. The ontologically vague notion of a superposition creeps in. Martin therefore chooses to maintain a realist/particulate ontology, and needs a reason for wave-like behaviour. "Flutter" is born (of particle-realist necessity). It is ad hoc, but the theory is that the comprehensible ad hoc is preferable to the nonsensical or the nonconceivable.

The situation can be taken in one of two ways. The first would be that flutter is a remarkable effect demonstrated by the double slit apparatus, and has more to do with "aiming" the particle than anything else - a peculiarity of the dispositional interactions in question. But this is too ad hoc, too simplistic, and somewhat senseless. We cannot just add some variable without examining the consequences. (Doing so would be bad philosophy, out of line with the William of Occam and out of line with taking things seriously.) Examining the consequences leads to a second interpretation of flutter.

If we see the area of space on the back side of the slit as being full of waves which relate to the Schrodinger equation , we must see flutter as the explanation for quantum behaviour in general. After all, if something is fluttering, we need to figure out when and why it is doing so, and what the rules are. Only one solution presents itself to my mind. What "flutter" amounts to is a claim that the curve the Schrodinger equation describes is actually linked to a dispositional property of the entity in question. Flutter, then, is the underwriter of Quantum Mechanics, if it is anything at all.

The general description of quantum systems might thus be less Observer-oriented and more disposition-oriented. We can conceive of the Schrodinger equation as a description of a particle's unmanifested disposition for some particular property, be it position, momentum, or whatever. Thus, a simple quantum system, like an electron in a box, is not necessarily to be conceived of as being in some sort of strange state of indescribable semi-existence pre-measurement (as the Copenhagen Interpretation suggests), but a "real" state (a dispositional state? A non-manifest state?), the precise description of which we must develop.[26] What we calculate (describe) with the Schrodinger equation is the dispositional flutter of the particle. Just what this means does of course require some spelling out. A good portion of what follows may be seen as an attempt at that.

With flutter in the picture, we now have some more refined dispositional conceptions of what could be going on in the double slit. The interference device provides reciprocal dispositional partners for either "wave" or "particle" manifestation. The "wave" manifestation occurs because of some not-quite-random predilections of the particles in question. Notice that we are no longer "creating reality" (whatever that could mean) at any point - when we observe via detector, we are just providing a manifestation partner. From a dispositional perspective, the confusion in the Copenhagen Interpretation is that the reciprocal disposition partner *happens* to be an observation apparatus, and the "observation" part was focused on, rather than the "dispositional partner" part[27].

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[26] And which may indeed end up being *a description* of superposition

[27] This is presumably because the notion of a reciprocal partner for manifestation was lacking. Without the ontological "map" it is extremely difficult not to get caught up in some sort of "observer oriented" ontology.

To explore this further, let us move back to Schrodinger's Cat with a dispositional ontology in mind. We put a cat in a box with a machine which may or may not kill the cat. We seal the system (with duct tape, or whatever - we don't need NASA to do this experiment - it's simple! The allure of the "quantum mystique" must be rejected.). The Copenhagen Interpretation suggests that the sealed-in cat is neither dead nor alive, nor both. It suggests the cat is in a weird mode called "superposition", and that's it until we "Observe" and collapse the wave-function and thus the superposition. It has, of course, been suggested that the cat is itself an observer, which I think is probably right (though irrelevant - the relevance is that the cat is a dispositional critter - more in the next paragraph). The Copenhagen Interpretation has no particular means of distinguishing what a detector is or isn't - what metaphysical makeup is required for the collapse of the wave function. Here we see how strange the Copenhagen Interpretation might become in the wrong hands - we now have to postulate that *human* consciousness is the key, if we don't want the cat to be a detector. If we do want the cat to be a detector, what else is? A mouse? An Oyster? We know where this road goes. Metaphysically speaking, the Copenhagen Interpretation is a disaster waiting (or not) to happen.

From a dispositional perspective, we can offer another solution. We can claim that the cat is either dead or alive and not both, and that we just don't know because we haven't looked. The mathematical situation does not give us any information about our particular cat, but it is not clear to me in what way this shows that our ontology must include such things as felines which are dead and alive and not neither and not both. The superposition metaphysicians must explain what a half-alive half-dead cat is like, and they can't. On strictly philosophic (epistemic?) grounds, the dispositional theory looks better, as that camp requires no incomprehensible states of existence (none other than the main - the existence of real potentials!). Notice that this little corner of the debate is nothing more than a "How much skepticism is the right amount?" problem. There is a leap from "don't know" (epistemic "knowledge" (or rather lack of)) to "can't know" (ontologic belief) which we may or may not take.

The disposition-realist's claim is that the cat's deadness or alivenesss IS, but isn't known. In a bit more detail, the state of the cat pre-observation is a manifest state (but still unknown), whereas an electron pre-observation may not be in a manifest state (but equally unknown). In the cat case, all the required reciprocal dispositional partners are present - the cat, the poison, etc. We therefore have reason to think that "reality" has occurred without the need of "Observation".

In the case of an electron, say, trapped in a potential-well (the "Particle In a Box" - simplest of the quantum systems), the dispositional partner required for manifestation (which happens to be the detector) is *missing*. Initially, what we want to say about such a system is that something is there, but it lacks quantitative properties as yet. This is the first step in developing a dispositional view of "superposition".

Synthesis: We can, with a dispositional view, "explain" the double slit experiment, escape the ontological pickle of Schrodinger's Cat without committing ourselves to any particular view of quantum systems which lack manifestation partners (quantum systems in superposition), and begin to describe such systems in a clearer way than has been possible before.

Beyond Copenhagen

Of further interest is that if Martin's view is correct, the "wave" manifestation in the double slit (the interference pattern on the screen) isn't *real* wave behaviour. It is pseudo wave behaviour generated by the flutter in dispositions - the "interference" pattern is now just a pattern: no "real" interference is occurring. Further, we no longer need to think of the particles as being in a superposition of going through both slits. Each particle has a single path. Martin's theory is a fully "realist" account, and wave-particle duality is nothing to be upset about. In a sense, we can just admit that we don't know what the DeBroglie wavelength is exactly, and go about our business.

What of this? Are we beginning to lay superposition to rest? Perhaps not. On top of our *very* casual treatment of wave-particle duality ("Hey, it's all particles after all! Quantum system wave-behaviour is caused by intrinsic disposition flutter!"), it seems to me that the ad hoc nature of dispositional flutter is getting a bit out of hand. Why should there be anything but "regular" (particle-like) behaviour after the slits if the particles in question are not interfering with each other somehow? There is no apparent reason. So while an intrinsic flutter of disposition does provide a way to view the Schrodinger equation, the postulate needs some beefing up when it comes to explaining *why* we see an interference pattern. Granted, the flutter *might* be such that what looks like an interference pattern develops, but isn't it a bit odd that this should be the case? *Isn't it odd that flutter for no apparent reason obeys wave equations*? We need a reason for the wave-like behaviour, particularly in light of our rejection of the Copenhagen suggestion that the particles are in superposition over both holes. (Note that we might still maintain a dispositional picture and accept that the "particle" goes through both holes - the wave/particle duality is easily held onto by the dispositional theorist, but some discussion of the "particle" in a pre-measurement state is still deserved. It seems easier to proceed with a "real particle" ontology. Martin demands that we *attempt* this, and Occam does too. Let's keep our postulates as simple as we can. If they fail, we'll add to them.).

At this stage, I must briefly introduce more ontologies (one of them I will utilize, the others purely for the sake of being fairly comprehensive). These are "quantum ontologies", and I think we must pick from these if we are to go "beyond" flutter while maintaining a dispositional particle-realist's view.

In 1952, David Bohm put forward a radical interpretation of the Schrodinger equation. Rather than as a mathematical device of prediction (viz. philosophic anti-realist), Bohm viewed the wave-function as some sort of descriptor of space in the region in question. Bohm's suggestion is that the universe consists of "real" particles, and "guide waves" for them. These guide waves (called quantum potential waves) are in part what the Schrodinger equation describes. The quantum potential being a reqorking of the Schrodinger equation with the phase of the wave in question accounted for. Thus, the interference pattern in the double slit is explained by the guide wave passing through both slits, and producing an interfering guide wave - such that the particles "riding" the wave are much more likely to follow certain parts of the wave, the antinodes, rather than the nodes. The antinodes provide, as it were, a deeper trough for the particles to ride in.

Bohm's theory then, is fully deterministic, discarding the ontologic haze of the Copenhagen Interpretation in favor of an epistemic haze of sorts. The suggestion is that we could know, in principle, what the result of any particular measurement was going to be if we knew with enough precision the initial conditions of the system (knew where on the guide wave the particle was and what its physical properties - velocity etc. were). We do not, in practice, know these conditions, and because of that, cannot make deterministic predictions about quantum systems. This is a critical point of philosophy and mathematics that is often missed. It was Einstein (for one) who pushed for the idea of *ensembles*, suggesting that quantum mechanical math was perhaps not indicative of ontologic indeterminism (as Bohr believed), but a kind of epistemic indeterminism. In this respect, Einstein's famous quotation, "God does not play at dice." is significant and misleading. It is significant because Einstein believed that every individual system is deterministic (that God could know the outcome of an experiment), but that the quantum math was not descriptive of individual systems (that the math was not a tool for predicting individual experimental results, but rather, statistical results of large groups (ensembles) of experiments). Einstein's quotation is misleading though, in that the rolling of a die is an excellent example of a deterministic system which only produces statistical results. With Newton's laws and enough information about the initial conditions of any particular throw of the die, we could calculate how the cube will act as it bounces along, and accurately predict which number would face up. However, we lack the initial conditions (the die is hidden in our hand), and so we can only say that the chance of any particular number facing up is one in six. "Indeterminism" in a deterministic system. Bohm's theory suggests that the quantum realm is analogous to the rolling of a die.

Another ontology which reconciles "real" particles and "real" interference in the double slit is called "Many Worlds" and it bears striking resemblance to "Possible Worlds" talk in philosophy, the key difference being that the many quantum worlds can interact with each other. Proposed by H. Everrett in 1957, the idea is that every quantum event fractures the universe into a (possibly infinite) number of other universes - each one containing a different "result" of the event. So here in "this" world I measure an electron as having spin +1/2, and the universe splits such that in another world "I" measure the spin as -1/2 at that time, personal identity issues not withstanding.

In the case of the double slit, it is suggested that the interference stems from the Schrodinger waves (which describe the space on the back side of the slits) from other worlds very like our own, which produce the interference pattern with the waves in our world, and vice versa. There is no interference pattern when only one slit is open, due to the fact that this difference is enough to "lose touch" with other worlds.

This theory is ad hoc, and lacks a mechanism of other-world interaction, as far as I can tell. While it may "explain" the double slit, "Many Worlds" goes only a very little way in helping to understand superposition, quantum mechanics, or the world in general.

For obvious, if not particularly philosophically sound reasons, I shall more or less ignore the Many Worlds idea, and instead try to incorporate a Bohmian perspective into the Martin-style explanation of the double slit.[28]

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[28] A little honesty goes a long way. I think "Many Worlds" is a strange attempt to get out of the difficulties which the "Collapse of the Wave Function" brings on. It is ad hoc, like so many of our ontologic theories. However, it strikes me as a rather desperate attempt to make some sense of the double slit, and the critical ingredients are missing - what are the rules for Universe interaction? Where else might this be seen? What work does this conception do as an ontology? While none of these questions is the foundation of a crippling attack against Many Worlds, that these questions exist is enough to put me off. Moreover, working in what might be called the "spirit" of Martin's work, we have no room, need, nor desire for so many worlds. The Duke of Occam can handle the rest of the philosophizing in that vein.

A third theory is Feynman's, his idea being that particles "choose" a path through space from many available paths. This concept is decently represented by imagining bundles of fibre-optic cables. On can imagine a particle coming to a particular point in space, and having to enter one of many cables, the subsequent path of the particle being determined by the cable it enters. Feynman's explanation for quantum statistics is that there happen to be more "cables" leading to certain areas than other areas, and this is what the Schrodinger equation calculates.

The similarity of Bohm's and Feynman's ideas is in my opinion a good thing, and I think much of what is said in regard to Bohm's theory can be said of Feynman's. For a more comprehensive look at Feynman's theory with regard to dispositions, see Aronson, 1998.

I want an explanation for the "interference pattern" in the double slit experiment (an uncommon want, when every week and month send forth a new one?). Martin's view allows us to construct something sensible to say about the experiment, but does not *explain* the apparent wave behaviour (except to suggest that it isn't). Disposition flutter could indeed be the reason for what we see, but if so, we are lacking some key ingredient as to why the flutter does what it does. Martin has suggested to me that we take flutter at face value, as a remarkable fact about the world; an intrinsic property which gets no further explanation. He feels flutter is, in some sense, primitive.

The ontological advantage of a more Bohmian view is that we have a *reason* to expect an interference pattern. There are "real" waves, really interfering, and setting up "space" such that the incoming particles are more likely to be found in some areas than others. This is a more satisfying answer than "flutter". The biggest problem is explaining *how* the Bohmian guide-waves manipulate the particles in question.[29]

That said, we are still on the track of an interesting ontology. We need to alter our dispositional conception slightly, in order to accommodate "real" (predictable? meaningful?) interference in the double slit. We need a wave-front to pass through the slits, diffracting and interfering. No "intrinsic" property is going to give us this.[30] Thus, we must look to some "outside source" for the interference; a wave of some sort. Can we incorporate a Bohmian wave with a dispositional ontology? I believe so.

The Schrodinger equation can be viewed as a means to calculate the probability of finding some entity in any given section of space, and the dispositional suggestion is that this might be seen as an intrinsic property of a "real" particle (let's use the term "flutter" again). What affects this property? Well, the Schrodinger equation has different solutions for different systems, and we might begin to suspect that the experimental arrangement is going to be the critical factor. This is in line with Bohm's theory as well - experimental arrangement will determine to some extent the "shape" of the quantum potential wave. Can we just force the two theories together, and suggest that there is a wave propagating through space, which somehow controls the disposition lines of the particle in question?

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[29] I find Bohm's own answer to that question difficult to understand. He analogizes the "guide wave" with a radio wave. A radio wave might "direct" a ship at sea, by providing information for it. Likewise, the particles in the double slit move under there own energy once the guide wave has, as it were, told them where to go. But how does this *work*? Electrons don't have captains, rudders, or propellors... In truth, Bohm's analogy is not so good, as his theory seems to "build" particles out of truncated waves, and thus, there is no "particle" to direct, only a localized wave-packet which interacts with the system. The "quantum potential" is in fact the phase of the wave, a critical piece of information about how any particular wave will act.

[30] Unless the "intrinsic" property is "waviness". This on its own is not impossible, but we are working within a conceptual framework the point of which is to remove such strange beasts from the world! Perhaps the sentence should read, "Within a particle-oriented realist ontology, no intrinsic property will give us such behaviour."

This is not far from Bohm's own thinking, apparently, as he says, "We may therefore propose that an electron too moves under its own energy, and that the form of the quantum wave directs the energy of the electron."[31]

The question, of course, is how this works. How does the "quantum wave" direct the energy of the particle? We still seem stuck on one or the other side of a thought-fence. We can understand the quantum wave as real, and *somehow* directive of the particles (or rather, of the particles' dispositional flutter), or we can take the flutter as the base entity, and be perplexed as to why it does what it does in the double slit.

Let us step back and look at the competing ideas. Martin's view is based on intrinsic properties, Bohm's on external waves "directing" particles. I assume Bohm was (unconsciously?) used to a substance-oriented ontology, perhaps akin to Armstrong's. Might we reinvent the Bohmian view with a property ontology on the table instead? If "property" is of fundamental order, it makes sense to assume that the Schrodinger equation deals in properties too. With a Martin-style dispositional view we see space-time as the "haver-unhad" of properties, and everything that happens can be described as property-events in space-time. The "Laws of Nature" would therefore be best seen (indeed could only be seen) as laws about properties. Given that, we might see the Schrodinger equation as descriptive of properties in space-time. In what way descriptive? The Schrodinger wave could be seen as related to how, as it were, "easily" a property can exist in space-time.

Instead of "flutter", the Schrodinger equation might just be a calculation of how well space can support a given property in a given region over time. We might see the

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[31] Bohm and Hiley, p.32

wave as preceding the property in question in a "real" way (Bohm style), and "setting up" space with respect to that property. Thus when we make our measurements, we find the entities/properties in question in certain areas more often than others. With a view like this, perhaps we can make more sense of Bohm's theory, while keeping the positive aspects of a dispositional ontology.

While Martin desires that the causal stories in the universe to be intrinsically oriented, suggesting that everything comes from the quark, I think the double slit gives us reason to doubt this (or reason to abandon a particle-oriented ontology. However, I never really did understand "wave-particle duality", so I'm going to keep working the other side of town.). The wave behaviour is best explained by some entity or element of reality which is not intrinsic to the particle in question (if a realist view is to be easily maintained). The Schrodinger wave is related intimately to the properties being dealt with, but it is, under any light, an extended part of that property (that is, it isn't "within" the particle in question. It precedes the particle and has an independent existence.). Space must be viewed as somehow involved in the bearing of properties, and we need to accommodate the notion of a wave in space (external to any entities in question), which seems to calculate how well properties are supported by space.[32]

In general, Martin speaks of space as "the haver of properties itself unhad (as a property)". This haver unhad, to speak like Aquinas, is at all times what we are talking about when we talk of "the world". This is the subtle peculiarity of a property ontology - tables don't reduce to anything but property instances (dispositions and manifestations) in

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[32] The rest of the "Laws of Nature" may be viewed in the same way. We have found a conception of "dispositional interaction" which will allow us to construct the laws of nature out of dispositions with no

space-time. And that's all *anything* is. Ever. Anywhere. It is much more intuitively charming to think in terms of atoms-as-billiard-balls than billiard-balls-as-property-clusters-in-spacetime, but such is life (and so much for Democritus...). Our ontology, then, is one which fits the world very well indeed, but only with the benefit of metaphysical hindsight, as it were. One needs to be reminded constantly of the model - to "sing it in the shower", as Martin would have it. Once we embrace this properties-in-space type of thinking, we may begin to make sense of otherwise puzzling circumstances.

In the case of the double slit, we find the Schrodinger wave giving us an interference pattern when both slits are open and no detector is operational in the slits. When we close one slit, or turn on the detector, the interference pattern vanishes. With regards to the former, this is to be expected, as the wave passes through only one slit. The latter situation, however, needs a story (and I haven't seen anyone give this story about Bohm's theory. Even Bohm and Hiley ignore the "detail" of what happens when we detect.) I think the most plausible answer, considering the type of story we are interested in telling (a story about "real" particles ("real" property clusters!) showing complex behaviour, with no half-alive, half-dead cats in the offing), is that the detector influences the experimental arrangement, and generates a "new" Schrodinger wave - alters the properties of the sector of space in question.

If we built an apparatus with two slits, one of which had a particle source in it, we would certainly not expect an interference pattern (the other slit is totally irrelevant). With this in mind, we see that with a detector on, we have, at the time of measurement, an arrangement functionally equivalent to the one described above (if no "previous" quantum

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tremendous gaps in thought. What is a magnetic field, if not a dispositional partner? We have a region of potentials are hanging about). So we find ourselves suggesting that the detector modifies the shape of the Schrodinger wave on the back side of the slit, and this we might well expect. We have changed the experimental arrangement in such a way as to also modify the Schrodinger wave(s) in question. (Popper is vindicated, as it turns out!)

We lose, then, the idea that in the double slit apparatus there are "wave partners" and "particle partners" for the particles in question. The partners involved don't modify the particles, as such, but modify where the particles are likely to be found. The suggestion is that we need not carry any ontologically queer entities into the double slit explanation - we need only "particles" (compresent-property-instances), and the quantum potential wave guiding them (okay, one queer entity).

This reinterpretation of the Schrodinger function fits well with a dispositional ontology. Being property rather than substance oriented allows for new ways of thinking about the experiment and its ramifications. We have had to rethink the reciprocal partners in the double slit, but this *way* of thinking is what allows us to formulate decent explanations. That said, we shall move on to further considerations in order to firm up the relation between disposition and superposition a bit more, as this still requires some spelling out. (And what with our shiny new interpretation of quantum mechanics emerging, how can we fail?)

It was suggested earlier that the notion of superposition had to be reckoned with for a serious quantum ontology to work, and I don't think that this has been accomplished with the psuedo-Bohmian approach outlined above. The approach is beautifully simple, and basically removes the nasty complications of half-dead half-alive cats from the world.

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space (described by an equation) in which particles tend to manifest certain behaviours.

But it may do so at the cost of mathematical rigour, so to speak. The fact that particular solutions to a particular Schrodinger equation add up to form a new solution must be dealt with.

What we need to address is the situation before measurement, as it is agreed by all that after opening a box with a cat in it, we find a cat, either dead or alive, and not some hypothetical mathematical object. Copenhagen got from hypothetical to actual by postulate, but this makes "measurement" ontologically relevant (critical!) and we wish to avoid such a postulate if possible. The disposition theory allows us to make principled statements about pre-measurement existence, however, and this yields up no puzzles about how consciousness forces the universe to participate etc. Simply put, manifestation occurs if and only if partnership occurs. The reciprocal dispositional partner is the necessary and sufficient condition of manifestation. This is why the disposition camp can argue for the actual manifest deadness or aliveness (at all times) of Schrodinger's cat. But can the disposition camp figure in superposition at the same time?

The disposition-realist is answering two masters. The first master is the desire to flesh things out dispositionally, offering a clear, causal account of the world, in whatever bizarre splendor he finds necessary. We might call this master "Conviction". The second master is plain old clear thinking, the careful spelling out of our ideas. "Clarity" for short.

We should like to think that our masters would work together but this is not always the case. The particular problem is this: a realist like Martin has certain convictions (like "realism", for instance!). These convictions drive his theorizing, but they also force him to reject some possibilities. Martin seeks a theory in which "real" particles are "carrying" dispositions which are doing the work, so to speak. Martin is not only a realist, but what I would like to call a "particle-realist". The particle realist believes that nature does the same tricks whether we are there for audience or not, and that the basic entities we find in nature have sets of definable characteristics at all times (notice that the definition has nothing to do with what constitutes a "particle". Martin's is a property ontology, and thus a particle can be no more than compresent properties like mass and charge, for instance. There are no little marbles "carrying" the dispositions.) Thus he combats the Copenhagen school, with their "hazy" entities and ontology of pre-measurement probabilistic fuzz. Yet at the bottom of Martin's ontology, what can we find? Fuzz. I promise.

At the very bottom of the disposition/manifestation picture, what do we find? Martin's answer is that we find individual "particles" - some "final" entity from which the rest of matter is to be built. These may be quarks or superstrings, or whatever the physicists dig up for us. Martin has suggested to me that these fundamental entities must have certain properties at all times. Properties like mass and charge - the very basic properties, must be manifest (ontically speaking) at all times. Thus Martin envisages the microscopic world much as Bohm seems to have - a complex realm of definite particles and their interactions/capabilities. This is a realist's refuge from the perplexing haze of the Copenhagen ontology. The master being answered to is Clarity.

Unfortunately, when we think about Martin's theory and the type of causal story it presents, we find ourselves opening a door through which the particle realist dare not (indeed cannot) go. Martin's theory is about manifestations through *mutual partnership*. All of his examples insist upon the mutuality of manifestation. The point is that if we accept Martin's theory outright (and we seem to have argued previously that we should, given the power of the story) we find not a world of easily conceived miniature-billiard-ball-electrons, but a world of fuzz.

Simply put, we have no reason to expect a mass, a charge, or any other manifest property until a mutual manifestation partner is in place. Given this, we have reason to think that the Copenhagen Interpretation of a particle in the box may indeed be correct. That is to say, in an extremely simple isolated system, we haven't the complexity required to force manifestation. The Copenhagen school is entitled to its belief that what we have in the potential-well is not an electron and also not not an electron. We have in the box a disposition (carrier), and no manifestation partner, and hence no manifestation. No position. No charge. No whatever. Only the dispositions for those things.

If our ontology is one of manifestation through partnership, then at the bottom level we either have some properties which manifest themselves without partners, or we have strange entities with no manifest properties. Conviction seems to triumph over Clarity at this stage.

Luckily for the model, Conviction also drives us back from this fuzzy world. The particle-realist has two moves at his disposal. He can claim that space-time is the only "partner" required for the manifestation of "fundamental" properties like mass etc. but this would be ad hoc. That something is ad hoc does not make it incorrect, but it certainly seems odd that we would have to abandon the partnership view simply because we don't like what happens when we find a simple system with no partners. That seems to be a dishonest maneuver.

A better explanation might come through the insistence that the case of the "simple" system is not in fact a real case (this is Martin-style philosophizing - if we find a case which does not fit the model, we must reject either the case or the model). This would amount to claiming that no partnerless entities exist. We might, for instance, suggest that the gravitational interaction between our hypothetical particle and the planet nearest to it (or even the electron nearest to it - it isn't a question of magnitude) is enough to bring about manifestation. Thus, the suggestion that a system could be "simple", with no outside interference, is in fact a misleading one.

There is of course some necessitarian fallout from the view presented above: as soon as there is more than one entity in the universe, we have interactions which make the entities manifest certain fundamental properties. We might loosely say that the fact that there is anything provides us with the fact that there is *everything*, that there is no partnerless entity in this universe and could never be (while there was anything else in this universe).

Of course we cannot be absolutely sure that the weakest of gravitational or magnetic or whatever type of interactions are enough to force a manifest state, but it fits the ontologic model as presented and the facts about the universe as we know them (that is to say, gravitational force, for instance, is proportional to the square of the inverse of the distance between the objects in question, and is therefore never quite zero). Thus we can continue to see the ontologic fuzz of the Copenhagen Interpretation as unnecessary baggage and we analytic philosophers are under careful instruction from William of Occam with regards to that.

Here then we find the dispositional view of quantum mechanics. Superposition is a description of the dispositions of a system, and in extremely simple systems we might find only the disposition, with no manifestation. In more complex systems, however, we find that reciprocal disposition partners are provided by the system and thus manifestations occur (sometimes accidentally related to measurement, as in the double slit, and sometimes not, as in Schrodinger's Cat.). The Schrodinger Wave is a calculation of how well space-time can support a property, and thus is related to the probability of finding property instances in space-time.

Bell's Theorem Violated

Reasonable success can been claimed in fitting a variant of Martin's dispositional ontology onto what have to be seen as the most baffling experiments we humans have done so far. Martin's story about the world gives us a new understanding of what the micro-world might be like. However, there is one more puzzle piece which begs to be dealt with. Bell's Theorem is an important idea which plays a central role in quantum mechanics.

While I have suggested that the paradox of Schrodinger's Cat can be dismissed as epistemic, that the cat's state is definite but unknown, Bell's Theorem (or rather, the violation of Bell's Theorem by quantum systems) may suggest otherwise. If this is the case, we dispositional analysts will have some fancy talking to do.

Bell's Theorem is relatively easy to understand but terribly difficult to explain. In wondering whether particles like electrons have a definite x-spin (and z-spin) while the y-spin is known (i.e. what is the complete description of the particles in the spin experiments discussed in the Appendix?) we bump up against a barrier of not being able to measure more than one spin axis at once on any particular entity. However, in 1964, Bell devised a way to test whether the values of the x and z spin "exist" when the y-spin is known. And the answer is no.[33]

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[33] I have given what I perceive to be the "received view" of the implications of Bell's theorem. Physicist R. Sreenivasan has suggested to me that some care must e taken in examining just what the violation of Bell's theorem means. His suggestion is that Bell's result proves only that we cannot extrapolate from one quantum variable to another. The question is whether this implies a "lack" of the extrapolated property or not. The received view seems to be that it does imply a lack, but I believe Sreenivasan's caution is warranted. I will operate for the purposes of this paper within the "most difficult" framework, in order to show that a dispositional ontology can work under the most dire of circumstances. If "reality" turns out to be more friendly to intuition than seems to be expected, well, all the better for everyone.

This answer comes about by measuring quantum spin of paired particles along different axes. If we build a machine which produces two particles at once, propelled in different directions, we can design it such that if one particle has an x spin of +1, the other must have x spin -1, and likewise for the other axes.[34] Thus, we should be able to know two variables at once of a single particle - we measure the x spin on one particle (call it particle A), and the y-spin on its partner (B), and extrapolate the information about the y spin state of A and x spin state of B. It turns out, however, that this extrapolation fails. Why is this interesting? Bell used quantum math to predict the failure (conclusive experiment was first performed by Aspect) and it seems to show that quantum variables like spin and angular momentum don't have values until they are measured.[35]

So it looks like the x spin state, or the x angular momentum, *really* is a valueless quantity if the y spin state, or the y angular momentum is known. This has been seen as supportive of the Copenhagen Interpretation, with its indeterminate pre-measurement existences. Indeed, without an ontological model, we seem a bit lost when hit with Bell's result. With dispositions, however, we might come to some understanding of what the pre-measured system is like. It is a system within which what exists is one or more readinesses (and associated quantum potentials). The readinesses, when manifest, cancel out other previously manifested properties. Thus, if we measure the x-spin of a particle, we "unmeasure" its y-spin - force the y-spin into a non-manifest state. This is a peculiarity of the system (and systems like it - this is predictable through mathematics). As soon as the x-spin is manifest, the y-spin is not. This is no problem from a dispositional point of

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[34] As spin is conserved, we could in theory break a complex spin 0 particle into one spin -1/2 and one spin +1/2 particle, or two spin -1/2 and one spin+1 particles, etc. Physics is so easy on paper.

[35] For a succinct explanation of Bell's theorem, I recommend Lindley.

view (as soon as solubility manifests, crystallinity ceases, and vice versa). The main point is that while Bell's theorem suggests that superposed entities are valueless, we can utilize dispositions in order to suggest that while *valueless* with regard to a certain property, the entity in question need *not* be neutrally disposed with regard to that property. Valuelessness implies lack of manifestation, not lack of disposition (and certainly not lack of "reality").

Bell's Theorem can therefore be incorporated into a dispositional ontology. We still have a choice to make, however, between forms of realism. Deviation from Bell's theorem by quantum systems implies that no "local reality" theory of the universe is correct. The term "local reality" is confusing, however, and we must carefully distinguish just exactly what we mean. The word "local" is the key - and what we've shown is not that realism is faulty, but that one form of realism is. It is faulty not to believe in particles, but to believe that any particular particle in the experiment has perfect independence. The experiment shows that the entities in question are correlated in some strange way. We now have to choose a means of fleshing out this correlation.

Bohm's theory would suggest that the correlating agent is the quantum potential - part of spacetime which "decides" for the particles which properties they will have. Tweak one end of the potential wave (by measuring the x-spin of one particle, say) and your "quantum reverberations" will be "felt" by the other particle. It's not a question of superluminality - we aren't "sending" a message faster than light - we're just exerting what has been called "nonmechanical influence". The idea is that the quantum potential is sort of one piece in the whole experiment, and any time it is affected in one spot, the whole "piece" is affected.

This view is perhaps difficult to understand because the quantum potential is a different type of thing than we are used to, and it is a somewhat abstract concept - a wave in space-time that guides particles (or properties, in the dispositionally re-cast "pseudoBohmian" view). How it works is still a bit mystifying, and as an ontological terminus, we could hope for more without seeming disingenuous.

Unfortunately, the other option is Copenhagen superposition, and while we need no new casting of space-time for such a view, we do need a concept of something existing without manifest properties.

Which is the lesser of these two evils? I think Martin would prefer the more Bohmian view, to which I have been referring as particle-realism. In this view, we wind up with a position something like this: that space-time is complicated property-having stuff is not surprising, and our lack of clarity regarding the quantum potential (the name we have applied to a description of how space-time operates) is perhaps born of hitting the bottom of the causal chain and having no more "why"s. Sooner or later, ontologists are bound to say, "Here's the picture. I don't know why it is the way it is, but that's it." To find a lack of clarity of conception right in the fabric of space-time itself is in a sense good luck, and once we get "above" raw space-time and start dealing in particles and cats and tables and minds, we can go pretty far.

For my part, I came into this paper thinking that Bohm's theory was better than the Copenhagen Interpretation. I still think that's true in general, due mostly to the implications of Schrodinger's paradoxical cat. The really tremendous value of the dispositional ontology is that we can pick out the good from both theories (Bohm and Copenhagen) without being ad hoc. To recap briefly, I think that the "paradox" of

Schrodinger's Cat can be laid to rest if we see the critical part of the interaction as the dispositional, rather than the "Observer" oriented. Thus we can assume that there is no such thing as a half-alive, half-dead, not neither and not both cat, which is an important step in developing a reasonable picture of the world. On the other hand, if we take seriously the suggestion that manifestation requires partnership, we find the upsetting but rather logical conclusion that in simple systems, systems lacking manifestation partners, entities have a probabilistic existence (which we might as well continue to call "superposition").

The ontologic middle ground is the suggestion that entities which do have manifestation partners do behave as the particle-realists like Martin and Bohm would suggest, but that without the requisite partners, a stranger entity exists. I would like to call this position "pre-manifest realism", realism with regard to the pre-manifest state of simple systems.

We might call the pre-manifestation state a "purely dispositional" state. However, the notion of a "purely dispositional state" is contentious. Martin does not accept that a "purely" dispositional state can exist, as the disposition in question must be for something - thus there is a qualitative element to the state (this stemming from the "surprising identity" of categorical and dispositional properties at the base level, according to Martin). However, it is not clear to me in what sense the qualitative can exist without the quantitative. It is generally agreed that the quantitative "stands in need" of the qualitative: "so much" must be "so much of something". The reverse relation seems to follow the same line, for it is difficult to comprehend the qualitative without the quantitative - if there is a quality (or property), must there not be an "amount" of it? If this is right, then the dispositional, being a state without manifest (quantitative) properties, is also somehow a state lacking the qualitative. It is therefore difficult to see in what sense the quality is "there" before manifestation. However, it has previously been agreed that the disposition in question is a disposition *for something* - and this is qualitatively oriented! What we seem to be in need of is better language.

Better language might come in the form of some sort of middle-ground descriptor of the property, pre-manifestation (Martin uses the word qualitative to cover this, but I think this needs some adjustment, as it has other connotations as well.) The dispositional state of a thing in superposition might be called a proto-property state, or some such thing. The property is ready to be there, the readiness is specific for certain manifestations - i.e. something distinguishes it from other proto-property states - but there is as yet no manifestation of "the property", so it might be misleading to say that the property in question is "there", pre-manifestation.

Unfortunately, it is difficult to generate a way of thinking and talking about something no one has ever witnessed, so to speak. Separating disposition from manifestation seems like a chore in itself, without the worry that something might exist without any manifestation. However, we do seem justified in asserting that a proto-property state might in principle exist.

Final Discussion and Conclusions

This concludes the "exploratory" section of the paper. I have tried to map a complex ontology onto complex experiments, and I believe that the fit is good. We can fairly confidently dismiss the Copenhagen Interpretation proper, with its superposed cats. In the case of the cat in the box, there is *no evidence* that we force the cat into a non-manifest state. On the contrary, with a dispositional view we may claim that evidence has been found which supports the idea that the cat's state is "real" - manifest, the whole time, and it either lives or dies, depending on the device in the box (that is, depending on the reciprocal dispositional partners provided by the system). We can't see the pre-measurement state of the cat (it's pre-measurement!), but that does not entail that the cat's existence is indeterminate in an ontological sense. All of the required dispositional partners are present in the cat case (and it is supposed that the requisite partners for *some* or other manifestation are present in every case). We can with integrity maintain our belief that the cat is either alive or dead in the box, and not in some mystical state.

I believe the Copenhagen Interpretation rests on a mistake - confusion of the epistemic for the ontologic. It can now be clearly laid out as to why the mistake was made. We have little in the way of means of getting any closer to the "dispositional reality" (the "superposed state", in Copenhagen talk) other than conceptual analysis, and the Copenhagen Interpretation was laying bricks for its own ontological sidewalk as it went. the hope was that every brick would be necessary. This happened to be false, and such is the danger of working with one particular set of concepts - it becomes impossible to see any options. It so happens that there is another story to be told (a different sidewalk to build) about the quantum experiments in question. The principle reason for this mistake is simple enough. It turns out that detectors (the key ingredient in *any* experimental apparatus) are the reciprocal partners for quantum-scale devices, and without detectors, not only do we have a lack of information (epistemic), but (it seems) a lack of *manifested* reality (ontologic). (Manifested in the metaphysical sense - it isn't a question of having something going on even though we aren't detecting it - the detection is an integral part of the going-on.) So the Copenhagen intuition of "The Observer" is a natural mistake, and in some senses, it isn't so totally removed from the truth - "Reality" does occur when we observe. It just happens that "Reality" also occurs if we don't observe. Conceptually, "The Observer" is unimportant. We need dispositional partners for manifestation, neither "Consciousness" nor "The Observer" nor anything else semi-mystical, to "break down the wave function". We need only dispositional partnerships to explain the results of our experiments.

Within the dispositional framework we keep the good of the Copenhagen Interpretation: superposition is not ignored (it remains a critical notion) and Bell's result can be tolerated *rationally*. Happily, we escape the two features of the Copenhagen Interpretation which seem intolerable - superposition is no longer totally shrouded in fog - it has been *somewhat* spelled out dispositionally, and we need no longer postulate any "mystical" metaphysical connections when we attempt to explain the breakdown of the wave function. Properties manifest when dispositional partners are provided (and the partners at the quantum level are often enough the detectors themselves).

Meshing Martin's theory of dispositions and manifestations with Bohm's ideas about the Shrodinger equation allows us to beautifully conquer difficult situations. Causal stories of great complexity can be told. The idea of a specific readiness for a particular manifestation is a great help in understanding the double slit experiment and Bell's result. The only difficulty found was explaining the wave-behaviour in the double slit, but that is rectified either by assuming wave-particle duality (which a particle-realist won't like), or assuming that the Schrodinger wave precedes the particles in the apparatus (Bohm-style) and sets up space with regard to the properties in question. This view of the Schrodinger equation generates an interesting view of laws of nature in general, namely, that they are descriptions of property-events. (It should be reiterated that wave-particle duality outright can also be accepted by the dispositional theory - the duality being no more difficult to handle than the duality of sugar tasting sweet but turning brown in a flame. Different reciprocal partners yield up different manifestations.)

I think this view fits within a spectrum of ontological views, all of which are tenable, but which require differing amounts of skepticism. The Copenhagen Interpretation has not been defeated, but I have argued that there is no reason to support it, and that we can keep our intuitions about cats in boxes if we outline a different theory. Such a theory might come in the form of the "pre-manifestation realism" mentioned earlier, with the assumption that very simple systems lack manifestation partners, and that this leaves us talking about a strange mode of being for such systems. Martin's own view is that pre-manifest states never exist, simply because the world constantly offers manifestation partners of various sorts. This brings us to particle-realism, which suggests that a property-clump in question exists at all times, and the dispositions manifested by such a conglomerate will depend on the reciprocal partners provided. We hook this notion onto the Schrodinger equation, and come up with the notion that it is a sort of disposition-calculator, and the manifestations of the dispositions in question will depend on the physical circumstances provided by the experimental arrangement.

At the bottom of Martin's ontology we do find an unorthodox sort of thing. Dispositions are best understood in terms of disposition lines - specific "real" readinesses over an infinite web. Intuitively, this seems intelligible. Armstrong and others will no doubt suggest that more explanation of what a disposition "is" will be required. If we fail to give that description, the onus seems to be on us to show why something indescribable is non-abstract. Of course, we can easily accept the abstract, Campbell style, as something real which is gotten before the mind through "abstraction" or just resign ourselves to the apparent fact that if a dispositional view is accepted, the manifestation-oriented part will be easier to discuss than the dispositional (and the dispositional may remain abstract). The dispositional may be easier to understand on a case by case basis than as any particular theoretic construction. We can intuitively understand a glass's readiness to break under certain circumstances. Indeed, in some senses, dispositions intuitively seem undeniable (and certainly Martin would argue that no story of the universe can be told without some form of "potential" creeping in). The previous attempt at dispositionally analyzing mystifying experiments is also (somewhat accidentally) an attempt to show why we should think that dispositions are "real" and should form an integral part of our ontology. If we can give a better description of quantum reality than has been given before, our more epistemic worries (about abstraction etc) may just have to be shelved. The dipositional program is undeniably moving forward, and this much cannot be said about many other projects in the same field.

Further Experiments

Another experiment which requires ontological footing is performed by measuring the quantum spin of particles, along the x, y, and z axes. For ease of conception/reading, I will use the terminology which David Albert uses in Quantum Mechanics and Experience - where for spin "along" the x-axis the term "hardness" is used, and on the y-axis, "colour". Thus, an x spin would be measured instead of "+1" or "-1", as "hard" or "soft" (y spin as "black" or "white").

We can design machines to detect what colour or what hardness any particular particle is[36]. The hardness machine consists of a device which splits an incoming beam of particles (I will call this part "the separator") into two paths - hard and soft - and detectors for emergent beams (I will call this part "the detector"). When we build these machines and play with them, what happens is puzzling.

If we send a group of, say, 10000 particles through a hardness detector, 5000 of them will come out hard, 5000 soft.[37] If we take the soft ones and send them through a colour detector, 2500 will come out black, 2500 white (Likewise, if we send the hard ones through a colour detector - the split is 2500/2500 black/white). So hardness detectors somehow influence colour, and vice versa. See diagrams 5a and 5b on the following page.

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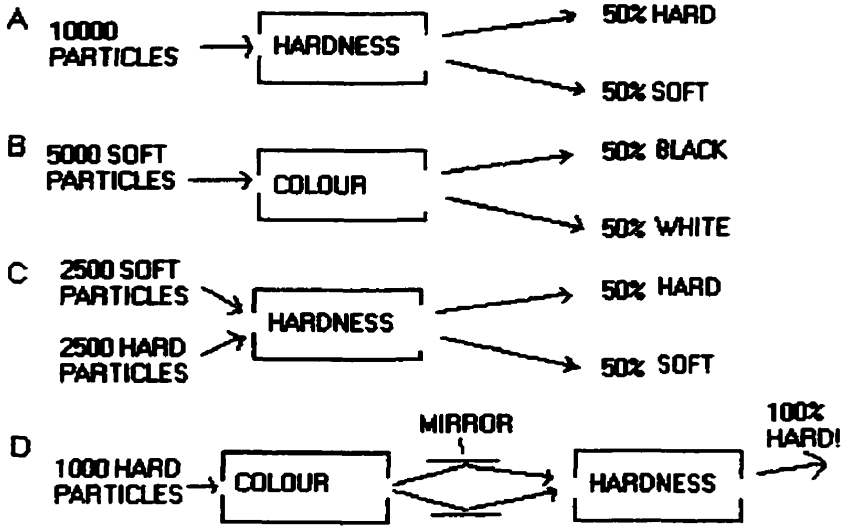
[36] The machines are known as Stern-Gerlach devices, and consist of a uniform magnetic field through the axis in question.

[37] This is not quite true. If we could get counted "batches" of electrons, there would still be some deviance in the 50/50 split, due to imperfections in the experiment (how do we know the history of these electrons?) and of course, good old fashioned experimental error.

Diagram 5.

A selection of hardness and colour machines.



Now the weird bit. If we put the 2500 black and 2500 white particles (all 5000 of which were previously measured as soft, remember) through another hardness machine, we find that 2500 come out soft, and 2500 hard. See Diagram 5c, previous page.

That is to say, whenever hardness is measured, it seems to "erase" any previous colour measurement, (and same for colour measurement influencing hardness - no surprise , as colour and hardness are arbitrarily assigned). One is a "reset" button for the other. This on its own is perhaps less surprising than we might think at first. The violation of Bell's Theorem by quantum systems seems to indicate that the properties in question do not "exist" all the time. That is, when we know the hardness of a particle, the colour of it is thrown into (what else) superposition - a valueless state. More on Bell's theorem later.

Here is the really strange part. If we take 10000 hard particles, send them through a colour separator, take the two outbound "beams" of particles and rejoin them (using mirrors) without detecting the colour, and *then* send the beam through a hardness machine, we would perhaps expect a 50/50 split for hard and soft (after all, in the other experiments, whenever we measured colour it "reset" the hardness). What we in fact get is nothing but hard particles. And this is mystifying. See diagram 5d. on the previous page. It seems the only difference in the experiments is the machine which recombines the streams after the colour separator.

Reworded. Send a bunch of particles through a hardness machine. Take the hard ones (or the soft ones - it doesn't matter), and put them through a colour separator, but don't detect the colour. Rejoin the beams which come out of the colour separator, and again run the particles through a hardness machine. What percent hard? 100. The colour separator seems to do something - there are two outbound beams - but it doesn't "reset" the hardness. The colour detector seems to do that.[38] See diagram D3, previous page.

It is generally assumed that the particles are in a superposition of white and black after the colour separator (before the detector) and the detector somehow breaks down the wave function and creates the colour "for real". But this is a very strange conception, as it isn't clear why the detector should have such power (why the colour separator only does some of the reality-work). (This is a specific form of a fairly standard complaint against the Copenhagen Interpretation - how/why is the wave function broken down? Notice however, that while the Copenhagen Interpretation is a bit befuddling, it seems the only interpretation which can easily be fit to this experiment! Once again, "Observation" seems to be the key.) Without an ontological model, there is little hope of further explaining what could be going on.

Dispositionally, we get the hint that the hardness detector is the reciprocal disposition partner (for manifestation), and the hardness separator is somehow a purely disposition-oriented device. How could this work?

We have to see the hardness separator as generating new disposition lines for the particles passing through (or at least sorting out previously established ones), i.e. hard and soft lines, which require a further partner (the detector) to manifest. Without the relevant partner, no manifestation. So if you take a group of hard particles, split for colour (rejoining the beams without detection), and measure hardness, you retain 100% hard

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[38] Or we can claim that hardness is actually never lost, and that the mirrors merely reflect the streams such that constructive interference occurs, re-establishing the hardness. This view only works in conjunction with a particular interpretation of the Bell result. See footnote 33 on p. 76.

particles because that manifested disposition wasn't destroyed. It must be that the "hard" disposition terminates when the colour disposition manifests. (It's a bit like the dynamite's explosive disposition terminating upon manifestation.)

The suggestion amounts to this. A "separator" sets up (or analyzes) the hardness or colour disposition lines, which require a further partner to manifest. If that partner is not presented, no manifestation occurs. The previous manifestation (hard or soft in the case we've been discussing) recurs (or continues to occur?) because nothing has blocked it or changed it. A particle's coming out of a hardness separator, say, in the "hard" stream, is not indicative of the particle's *being* hard, but rather of the particle's *readiness* to be hard. So we have a dispositional description of the "superposition" in question. The particles remain in a non-manifest state until the appropriate partner is provided, and once this occurs, the old manifestation is destroyed (more on "how destroyed" later, in a discussion of Bell's theorem).

It may not yet be totally clear how we are to conceive of the particles in these experiments. Let me try to clarify. Because there are two outbound beams from say, a colour separator, there ought to be some difference in what the beams contain. The difference, as noted previously, must be the disposition to be white (for one stream) and the disposition to be black (in the other). With this conception, we can see the superposed state as being a dispositionally "unfulfilled" state, with "real" particles which have complex behaviours. Let us proceed by analogy. Imagine an airport lobby with two doors. One might be marked "Amsterdam" and the other "Helsinki". Through each door is a plane which will go to the respective city. Travelers might go through one of these doors and wait around in the departure lounge - ready to go to Amsterdam, for instance. They aren't in Amsterdam, but they are getting ready to be so - they have separated from the "Helsinki" group, after all. And yet the flights could be canceled, and everybody would be put back together in the airport. The behaviour of the people is complex, with more than one element necessary for a successful trip - for the manifestation of the property of "been to Amsterdam" or "been to Helsinki". If we analogize to the spin experiments, we can maintain a realist picture while keeping the apparently necessary elements of superposition (i.e. describe what might be happening during the experiments - describe the part of "reality" that the quantum math ignores). After the colour separator, the particles are ready to be a certain colour, but haven't achieved it yet (they have a ticket to Amsterdam or Helsinki), and if no disposition partner in the way of a detector is provided (the flight is canceled), the particles won't manifest a colour and won't lose their hardness (the travelers in the example would not make to Amsterdam, so the last stamp in their passport would remain "Canada", to complete the analogy (to really complete it, we would also have to imagine that the customs officials in Helsinki and Amsterdam rip the page with the Canada stamp right out of the travelers' passports, as the particles in the experiment have their history "erased" upon manifestation.)). We can tell a story about the readinesses of the particles which by no means diminishes the identity of any particular particle nor implies that the particles are in some completely indescribable state. The "superposition" is conceived of not so much as "not white, not black, and not both and not neither" but as "ready to be black or ready to be white". And here is our general solution to the notion of superposition: it is not so much that the superposed state is indescribable, but that it is difficult to describe because one needs to think in terms of property readinesses rather than properties. Once we understand this, it begins to make sense when we say of a particle that its x spin is neither up nor down nor both nor neither. It *is* neither up nor down, but *it is ready to be*. There is a sort of second-order reality to get ahold of, and disposition/manifestation talk lets us do so.

One more question needs answering, and because we have accepted a modified Bohmian view, we can answer it. The question is, "How do the separators work?" and by this we are asking what a separator does, dispositionally, and why a separator doesn't force the particles into their new manifestation. The Bohmian view on this is that a separator is merely a sorter-out of which part of the quantum potential wave the particles are riding on (so the separator does not provide dispositions after all, but rather sorts out previously existing ones). Random variation in velocity vectors and initial positions accounts for the 50/50 split we find in the experiments. As soon as the particles are part of the experiment, they have readinesses with regard to the machines. A colour separator produces not coloured particles, but particles which are ready to be coloured (according to their relation to the quantum potential) and still have the manifest property of hardness (or softness). We can easily accept this view with our modified quantum ontology.

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