Yes, God Can.

A response to articles on quantum divine action in the September 2000 edition of Zygon and in particular a response to the work of Nicholas Saunders titled: *Does God Cheat at Dice? Divine Action and Quantum Possibilities*

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November, 2002

Abstract: An investigation of the discussion published in Zygon on divine action. The characterization of quantum mechanics as deterministic, the view of the nature of measurement and of Bohm's interpretation of quantum theory is evaluated and compared with recognized authorities on quantum mechanics. A simple theory of divine action based on quantum collapse is proposed and found to be in harmony with the concepts of quantum mechanics. The observation is made that there is a tendency to avoid the consideration of the indeterministic nature in quantum mechanics, and to actually argue for a deterministic nature of quantum mechanics despite a consensus in physics that quantum mechanics is indeterministic.

1 Introduction

Nicholas Saunder's article in *Zygon* is a challenge to the proponents of divine action through quantum indeterminacy. Saunders argues that the effects of divine action based on quantum indeterminacy at the quantum level can only have very minimal effects that are not sufficient to allow God to effectively intervene in a manner required to perform the actions wanted. Saunders claims that quantum divine action cannot fulfill the hope that theologians have of having found a "loophole" (518) that would allow them to defend special divine action. Saunders doubts that the character of quantum mechanics is indeterministic, citing alternate interpretations of quantum mechanics. Science has given us a highly deterministic precise picture of the world in quantum mechanics (523) that theologians are trying to escape through theories of divine action involving quantum indeterminacy (524).

Peter Hodgson's contribution in the same volume of *Zygon* goes even further in questioning indeterminacy. "We need to confirm that material reality is indeed an indeterministic system" (Hodgson, 2000, 506). The burden of proof rests on the side of indeterminacy. It is natural to assume that the world is deterministic. Hodgson claims that indeterminacy was uncritically accepted based on James Cushing's work on the history of Quantum Mechanics in 1994. History could have played out a different way and we would not have to discuss indeterminacy would it not have been for "the persuasiveness of Niels Bohr" (506).

Following Einstein's argument Hodgson claims that quantum mechanics is incomplete since it only results in a statistical description (507). The "inability to measure any physical quantity with unlimited accuracy does not imply that it does not have a precise value" (509). Measurements can be made to an arbitrary precision if we are willing to accept that a particle has a history. We can measure the complementary value later and therefore be more accurate than Heisenbergs Uncertainty principle permits (509). Bell's theorem about hidden variables was based on incorrect assumptions and therefore a deterministic theory of quantum mechanics is possible (511). Hodgson suggests that a "deterministic substratum to quantum mechanics" (514) exists.

Surprisingly Hodgson has no problems with God performing miracles. God made the laws and can also violate them as needed (514) and is not bound by the limits of quantum mechanics. Hodgson's major ax to grind is the deterministic nature of quantum mechanics. The theological issues can be resolved in a rather simple way. Hodgson's contribution to the discussion about divine action is his strong scientific background (over 50 publications spread out over decades mostly in nuclear physics). The problem with his expertise in a theological journal is that it is difficult to find persons with enough expertise to evaluate the contribution. Some of what I see in Hodgson's arguments is at variance to major authorities and with the textbooks on the field of quantum mechanics that I have read. Hodgson wants to change the way quantum mechanics is understood.

Jeff Koperski elaborates on the idea that theories of divine action by quantum determination can only have very limited effect (Koperski, 2000, 546) (as also argued by Saunders) since the indeterminacies only come into play when measurements are performed and investigates how chaos could amplify the minuscule effect. Koperski argues that random quantum events are washed out on a macroscopic scale in particular due to the nature of quantum mechanics to only interact by exchanging discrete quantities of energy (553). Quantum mechanics is not compatible with classic chaos as we know it (555). Koperski's final judgment is that many issues need to be addressed regarding the idea chaos amplifying quantum events. Koperski's material is only useful for the special situation where chaos theory is considered as an amplifier of minimal quantum fluctuations. There are other ways of amplification of quantum fluctuations discussed by Helrich (Helrich, 2000, 501). The approach presented here does not rely on amplification of quantum fluctuations by quantum chaos.

Gregory Peterson argues that quantum mechanics is ambiguous on the issue of indeterminism (Peterson, 2000, 883). Indeterminism is a matter of interpretation of quantum mechanics. Peterson claims that in the past many philosophers have accepted a mechanical determinism of the world and struggled to reinterpret theology and philosophy to be in conformity with determinism (884). It is wrong to let science have a final say on the issue: "Science is not metaphysics, and to reify any particular scientific theory is to deny the empirical character of science itself" (884). On the issue of God being bound by the laws of nature Peterson observes that it depends on the nature of the laws of nature. "If the 'laws' of nature are statistical in character or are limit cases, the issue of divine action becomes less acute, for the notion of 'violation' disappears" (885).

Thomas Tracy accepts Saunder's critique that what God can do through the determination of "indeterministic quantum transitions" (Tracy, 2000, 893-895) could be limited. But God's primary function is as the "creator of all things". God is therefore at the basis of all things. God not only has the potentialities available to him but has created the potentialities themselves. If God had created a deterministic universe then all processes in creation would have a fixed way of unrolling. God could have "enacted" history but would not be acting within it. Proposals for how God could act in the world might be theologically unnecessary (894). But such an approach would mean that God would not be able to respond to human actions. God has to interact with his creatures through some means and indeterminism would allow God to interact without violating the laws of nature. Tracy agrees with Koperski on the caution regarding quantum chaos, but notes other mechanisms in nature that amplify results of chance events at the quantum level (898).

Keith Ward sees quantum mechanics to be a "highly contested theory" (901) and objects to his theory of divine action as being characterized to be dependent on indeterminacies. Quantum mechanics could be replaced by a better theory that would explain indeterminacies(902). Ward sees that any intentional action by an agent (such as a person or God) must cause events to occur that the laws of nature alone cannot explain (903). By necessity there are gaps between the physical explanation and what happens in a "purposive process" by an agent. Laws do not completely explain all the events that occur. "There must be gaps in physical causality if God is ever to do anything" (903). These gaps could be quantum indeterminacy but must not necessarily be. "Indeterminacy" might exist at a macroscopic level as "insufficiently determined physical processes" (904). Ward's contribution is to show that some form of "indeterminacy" must exist for the exercise of free will. If the world were deterministic then free will could not be exercised and a purposeful action as a result of the will of an agent would not be possible.

Carl Helrich's contribution titled "*Measurement and Indeterminacy*" describes the basic concepts involved in thinking about quantum mechanics and measurement and the nature of indeterminacy (Helrich, 2000, 489-498) thereby correcting some of the issues in the other responses. Helrich conceptualizes the aspect of divine action by thinking as if the brain would be performing a measurement (490). The brain is a "large composite quantum system" (490) that is now performing like a measurement apparatus in a laboratory.

Helrich is very aware of the difficulties of such an approach because:

1. There is a difficulty in defining the boundaries of measurement (499). What exactly is the extent of the quantum mechanical system that is measuring?
2. We do not understand the connection between the neural net and consciousness (500). Potentially the conscious state of the individual (maybe as a set of supervening states in the brain) could cause the measurement.
3. How do we comprehend "self-measurement" and the consequences for the neural net (500)?
4. In a regular application of quantum mechanics a relation is established between the quantum mechanical system and some microscopic quantity. We do not understand the "quantities" that might be relevant for our consciousness (500).

Helrich suggests that the study of quantum indeterminacy in order to find how God interacts with us is to look at the wrong level of nature. The higher levels, such as consciousness, will be key to solving the issue. Large composite systems are involved.

Therefore the solution of how God interacts with us needs to be found at a higher level (503).

Helrich's way of reasoning is very conscious of the limitations that our lack of knowledge imposes on the discussion. He is right in that the ultimate solution to how divine interaction works in the human sphere must also include the higher levels of consciousness. The discussion here tries to limit theories of divine action only to the basic level of quantum mechanics and does not attempt to discuss higher levels in order to focus the argument.

Given quantum mechanics, could God work through indeterminacy? That is what Saunders is discussing. Helrich does not address Saunder's contention that indeterminacy only allows God to do minimal things. The question is: Does quantum mechanics give an openness so that God's action at higher levels will be possible? Helrich implicitly suggests that by entertaining the possibility that God could communicate through the quantum system of the brain.

This article is an attempt to respond to Saunders and the other contributors in *Zygon* with a proposal of how divine action could work. A key to the proposal of how divine action could work lies in the nature of the laws of nature and the nature of quantum mechanics. The following pages wrestle with that issue.

2 The People of London and the Laws of Nature

Saunders uses an analogy to quantum mechanics first proposed by Bertrand Russell to illustrate some of the basic issues in quantum mechanics (Saunders, 2000, 519). That analogy is also useful in this article to clarify what exactly is being proposed as to how divine action could work. The analogy is developed here with some additional explanations and comments.

A giant is observing London and can only perceive people in millions. For some reason the giant is limited in his perceptual ability. The giant has an inability to discern individual movements of persons (519). The giant notices large quantities of people moving into and out of London and observes regularities. One of these regularities is, for example, that there are more people in London during the day than at night.

Quantum mechanics is like this giant observing London. Classic experiments in physics usually involve large quantities of quantum particles. The giant sees quantities of people moving around and can describe those movements through laws. The giant might conclude that these are *scientific laws of nature* since the movements happen with a regularity that (almost) never changes. On a larger scale this law is very accurate but if the giant chooses to reduce the number of people under investigation, then the law develops an inaccuracy and the challenge to the giant's perceptional abilities surface. If applied to the individual it can only describe a probability that a person will go to London but it cannot be used to predict if an individual will go to London on a particular day.

A similar analogy is used by Bohm to introduce his interpretation of quantum mechanics (Bohm, 1981, 68). Concrete factors (such as health) determine the movement of individuals. But there are also different factors at work that determine the movement of people viewed in millions. London contains more people by day than by night because people work in the city. An individual might stay home because of an illness. Such an event would not be visible at the higher statistical level because at other days other people would be ill. The illness might not be recognizable because of the limitation in the giant's observational abilities. The assumption of a constant sickness rate is necessary that would be most likely expressed in the percent of the population being sick each day.

The analogy is useful to exemplify how divine action could work. Suppose one day there is royal wedding of the successor to the throne of England, the Prince of Wales. Suddenly the movement patterns of the population would drastically change. Since the giant can observe bulk movement the change would be obvious but considered to be irregular. The giant would have grave difficulty determining what caused this change. The pattern of the population's behavior would soon revert back to normal. A one-time event has occurred. The giant cannot compare this incident with any prior events or correlate what happened to regularities he has observed before. The event would cause great amazement to the giant. He could dismiss the change as a fluke wondering about the accuracy of his measurement devices. Any further investigation by the giant would be fruitless since the giant does not have the ability to produce another royal wedding nor investigate on the level of individuals what happened. The giant could wonder about this event and try to investigate and experiment in a variety of ways but would be unable to repeat the same event again.

When we talk about divine action we mean that something like an epidemic happens at the quantum level affecting large quantities of particles so that the commonly observed regularities at a higher level seem to change and extraordinary things happen. A royal wedding is rare, though, and not reproducible. It is rare that large quantities of quantum particles act together. The situation is not repeatable and therefore cannot be scientifically investigated.

Given this scenario Bohm sees the necessity to develop methods to analyze sub-quantum behavior to explain the reasons for the behavior of the quantum particles (the individuals) (Bohm, 1981, 69). Bohm essentially wants to equip the giant with the ability to observe the individuals and has the giant build theories on the movement of individuals. The dispute in science is about the possibility of the giant being able to observe individuals in London by some tricky means despite the perceptional challenge.

The search for a way to measure or access the sub-quantum level (not subject to Heisenberg's Uncertainty Principle) (Bohm, 1981, 106) has so far been unsuccessful. The validity of the Heisenberg Uncertainty Principle (the perceptional disability of the giant), which states that there is a fundamental limit to what we can observe, has been well established in countless experiments. Since limitations are a nuisance to scientific investigation strategies were developed by leading scientists such as Einstein over decades to prove the Heisenberg Uncertainty Principle wrong, but without success (Greenstein and Zajonc, 1997, 51).

Divine action in the above scenario can violate common regularities at higher level. The traffic situation in London can be totally different on a very extraordinary day but always be following certain patterns on other days. Similarly divine action does not violate laws of nature if they are seen as being of a statistical nature (Peterson, 2000, 885). But such an understanding means that quantum events can violate the laws of nature if those laws are understood in an ontological way as being an accurate reflection of the nature of reality. Then such an event would require a suspension of the (ontologically seen) laws of nature. A freak incident like described above can be tolerated by a statistical law.

This kind of divine action is noninterventionistic because it affirms the correctness of established scientific knowledge. A rare extraordinary quantum event (even involving large quantities of quanta) does not change the statistical average. Statistical averages are build over long periods of time using a large number of samples whereas the extraordinary quantum event only occurs once. The multitude of normal quantum events will cause normal statistics for large samples. Saunders concedes that one possible view of the laws of nature is that they have a statistical nature. The "founding fathers of quantum mechanics" recognized this (519) and today that character is widely accepted (520). It should be added that even Bohm, one of the fathers of the pilot-wave theory, accepted the conceptualization of laws of nature as of a statistical nature (Bohm, 1981, 68 / Bohm, 1957, 24).

Helrich discusses an experiment with photons (Helrich, 2000, 493). Individual measurements of the movement of the photons are indeterministic. But if large quantities of these photons are observed and an average is calculated then the results correspond to the classic theory. The experiment verifies that a scientific law is an emergent property from the individual photon behavior and is a nice illustration of the statistical character of the laws of nature. The assumptions that these regularities are "real" in terms of an ontological existence that nature has to follow is therefore mistaken and most likely a historically conditioned way of thinking. Statistical laws cannot be violated by isolated events.

3 Indeterminism and determinism

3.1 A criterion for indeterminacy

The problem in particular in the philosophical and theological writings on divine action, is that determinism is defined in a variety of ways. I will be making an attempt to pin down a criterion to check for indeterminacy in the following discussion. This will make it easier to check for determinism and indeterminism.

Indeterminacy and uncertainty are at the core of quantum mechanics. Without both, quantum mechanics does not exist. Here is a quote from Feynman's lectures on quantum mechanics, which is a classic treatment of the subject still in use as a textbook for classes on quantum mechanics today:

> The uncertainty principle "protects" quantum mechanics. Heisenberg recognized that if it were possible to measure the momentum and the position simultaneously with a greater accuracy, the[sic] quantum mechanics would collapse. So he proposed that it must be impossible. (Feynman, 1965, 1-11)

Therefore the distinguishing mark of indeterminacy is the inability to predict certain variables at the same time. Heisenberg and Feynman here claim that quantum mechanics would not be possible without this core element.

A *deterministic theory* of quantum mechanics would therefore have to be capable of allowing the prediction of both momentum and position of a particle. We will only accept a theory that satisfies this criterion as deterministic. If a theory defines determinism in such a way as not allow the determination of position and velocity at the same time then we cannot label the theory as deterministic.

If a theory is indeterministic then it needs to be established if the indeterminacy is of an *ontological* nature or a consequence of our *epistemology*. *Ontological indeterminacy* would mean that the indeterminacy is a fundamental characteristic of matter itself. If the indeterminacy is of an *epistemic nature* then quantum mechanics might be deterministic. We are just incapable of determining the outcome because of our human limitations. We might be able to give a theoretical account how the outcome can be determined.

The distinction between epistemic and ontological indeterminacy cannot be established by experiment because both are evident in experiments as us being unable to predict the outcome. Fundamentally the distinction is of a theoretical nature.

3.2 Common Quantum Mechanics

Common Quantum mechanics simply affirms that uncertainty exists as a core characteristic of quantum theory. It is not possible to predict the position and the velocity of a particle. Bohr's and Heisenberg's understanding of Quantum Mechanics (which is frequently referred to as the *Copenhagen Interpretation*) affirms that this is indeed the case and that this uncertainty is a reflection of the nature of matter. There is *ontological indeterminacy* in quantum mechanics. There is no trick to go beyond indeterminacy and find regularities behind indeterminacy since there is nothing behind it. The search for regularities to explain indeterminacy is useless.

Indeterminacy is useful for the explanation of core features of matter. The stability of atoms is explained, for example, by quantum mechanics and seems to be made possible by uncertainty (Penrose, 1997, 54). Quantum theory has been widely successful and has been experimentally verified over and over.

Saunders is wrestling with the nature of quantum theory and tries to characterize quantum theory as being deterministic: “The key point is that current quantum mechanics is both extremely deterministic and potentially indeterminate” (Saunders, 2000, 524). But still “It is not unreasonable to assert that quantum mechanics is ontologically indeterminate” (536) thereby characterizing the view of quantum mechanics as being indeterministic as a minority opinion whereas just the opposite is true. Quantum theory is generally accepted to be indeterministic without qualification (Feynman, 1965; Dirac, 1958; Penrose, 1997; Weinberg, 1994; Peebles, 1992).

Saunder’s view of quantum mechanics as being deterministic is based on Ernest Nagel’s evaluation of the equations of quantum mechanics (525). But Nagel does not claim that quantum theory is deterministic. The only claim made is that the equations of quantum mechanics (such as the Schroedinger equation) are of the same character as in classical theories (Helrich, 2000, 497). The notion of state in quantum mechanics includes indeterminacy. State vectors are usually sums over possible states and wave functions consequently result in sums over probabilities of possible measurement outcomes (Helrich, 2000, 496).

Classic theories can start with determining an initial state exactly and then calculate future states based on the initial state. In quantum mechanics the initial state itself is not determinable since any attempt to determine the state involves measurement, which is limited by the Heisenberg Uncertainty Principle (Eisberg and Resnick, 1974, 152).

Raymond Chiao explains that the specification of a wave-function to describe a quantum state requires the description of the physical system everywhere at the same time (Chiao in Russell, 2001, 17-18). The physical system that influences the quantum state can have a long reach in particular due to possible non-local effects. The event horizon (relativistic light-cone) limits what we can know about the world which further limits our ability to specify initial conditions.

Therefore a classic calculation of a deterministic result is impossible. But there is a definite deterministic element in the wave function. Weinberg describes the situation in the following way:

> During the times between the measurements the values of the wave function evolve in a perfectly continuous and deterministic way, dictated by some generalized version of the Schroedinger equation. While this is going on the system cannot be said to be in any definite configuration. If we measure the configuration of the system … the system jumps into a state that is definitely in one configuration or another, with probabilities given by the squares of the values of the wave function for these configuration just before the measurement" (Weinberg, 1994,75)

While the wave function might develop in a deterministic manner the measurements are still not deterministic. During the "deterministic evolution" the configuration of the whole system is not determined. The criteria that we have established in 3.1 is that measurement for position and velocity of an electron are possible. Even with the deterministic evolution of the wave function there is still the limitation on the measurement of position and velocity.

It is commonly known that the deterministic character of the wave function does not imply a deterministic nature of quantum mechanics itself. Only if we imagine that the wave function is what is real and not our measurements then will the theory be deterministic (Weinberg, 1994, 79).

Therefore the sense in which quantum theory is deterministic is restricted to looking at the equation and discarding the indeterminate nature of the state vectors and wave functions used by these equations.

Scenarios of a single particle system where all elements of the state vectors are known can be envisioned (Helrich 2000, 497) . But the usefulness of such scenarios is very limited because such a single particle system cannot interact with anything. In particular the interaction with a measurement device will cause the measurements to be indeterministic. Such scenarios are therefore of a more hyperthetical nature. They can be imagined but not verified since the scenario is not measurable. The reality of such a single particle system might be assumed in the context of a theory.

Saunders argues that quantum mechanics is only indeterministic at the point of measurement (Saunders, 2000, 525). Measurement is necessary to obtain any information at all. The effect of Saunders' argument is that quantum mechanics is deterministic if we have no information about the quantum mechanical system under observation. Any information obtained would require a measurement and therefore introduce indeterminism. Like in Helrich's example of the single quantum system before there is no information obtainable from the system since it cannot interact or be measured without risking indeterminacy.

The "determinism" of Saunders et al. seems to be mainly a matter of wordplay. Helrich can claim quite to the contrary that measurement is the point where quantum mechanics is definite and accurate because any measurement will "result in a specific value for the parameter measured" (Helrich, 2000, 496). Indeterminacy in quantum mechanics does not mean the inability to measure but expresses a limitation on the predictability of the outcome of that measurement. All quantities of interest can be measured as in classical physics. There are limitations on our ability to determine beforehand (in the sense of prediction) what the outcome of a measurement would be. It seems that the word *deterministic* is attached to various features of quantum theory to create the impression that quantum mechanics is deterministic.

3.3 Bohm's Interpretation of Quantum Mechanics

Saunders covers Bohmian quantum mechanics (also referred to as the pilot-wave theory) with the claim that it is "a totally deterministic theory" (Saunders, 2000, 527). Hodgson has the same expectations. Yet in Bohm's own words indeterminacy is a "reflection of the real behavior of matter in the atomic and nuclear domains" (Bohm, 1981, 67).

These contradictory statements need an explanation. When Bohm refers to "indeterminacy" he refers to the behavior of matter observed in a laboratory. Saunders and Hodgson meaning of "determinism" here is *ontological determinism*. All agree that matter is *indeterminate* as a phenomenon encountered in the laboratory.

Bohm assumes that there is a quantum field Q that causes this indeterminism by having a seemingly random influence on particles traveling through the field. Bohm's interpretation of quantum mechanics is only deterministic if the quantum potential Q can be calculated. The Q force is the highly non-local quantum field and its force does not diminish with increasing distance. Q is very peculiar because it depends on a theoretical force exerted by all particles of the universe on all possible locations in the universe. Q can theoretically be calculated if all particles of the universe are factored in (Bohm, 1981, 80). For all practical purposes Q is not determinable and therefore even Bohm's interpretation of quantum mechanics is only deterministic in theory. Bohm's theory suggests that indeterminacy is a *epistemic* problem. We cannot calculate the outcome because we are unable to factor in all particles in the universe. This enables the re-labeling of indeterminacy to "unpredictability" and allows Saunders to claim a deterministic quantum theory exists.

If we wanted to obtain the position and the velocity of our electron according to the criteria established in 3.1 Bohm's theory would only be able to calculate both if we would assume the universe to be smaller. Typically calculations are made with a restricted environment where Bohms theory works. But the universe is much bigger than just a few particles.

Bohm's theory accurately reflects the observed indeterminacy of quantum theory. The reason given why we cannot obtain the complementary measurement is different though. In Bohm's theory the particle travels on a trajectory that is interfered with by an un-measurable undetectable non-local quantum field. This quantum field causes a disturbance that does not allow us to predict position and velocity at the same time. We have no means of determining that quantum field in a satisfactory way. Therefore

Bohm's theory does not allow the determination of position and velocity of the electron and consequently Bohmian quantum mechanics is not deterministic according to the criteria of 3.1. What is claimed is that indeterminacy is observed for *epistemic* reasons and not because of *ontologic* reasons.

Bohmian quantum mechanics becomes deterministic if the lower level beyond uncertainty would become accessible to us. If the giant would develop the ability to discern individuals then we would be able to resolve the riddle. Bohmian Quantum mechanics has promised exactly that for a long time but has never delivered.

Standard textbooks such as Peebles, 1992; Feynman 1965; Dirac 1958 affirm the ontological indeterminate nature of quantum mechanics throughout and do not even mention the pilot wave theory. Peebles affirms Bohm's contributions to quantum mechanics through the restatement of the EPR paradox (Peebles, 1992, 247) and the discovery of the Bohm-Aharanov effect (Peebles, 1992, 155) but never mentions Bohm's Q potential.

The pilot-wave theory is not scientifically acceptable. Uncertainty is overwhelmingly affirmed in the field of quantum mechanics. Peebles argues that local hidden variable theories must be wrong according to Bell's Theorem. An assumption of a non-local hidden variable theory (such as Bohmian quantum mechanics) is unacceptably contrived and therefore the common conclusion of physicists is that "there is not a non-statistical theory underlying quantum physics" (Peebles, 1992, 244).

Saunders and others express the hope that Bohmian quantum mechanics will finally overcome common quantum mechanics (Saunders, 2000, 524). The riddle of indeterminacy will be solved shortly through such approaches as Bohm and through the Grand Unified Theory (GUT).

Weinberg is one of the proponents of the Grand Unified Theory and has written a book titled *Dreams of a Final Theory (*1993*)* where the history of the search for the GUT is presented. Weinberg then makes some statements regarding quantum mechanics and how he expects it to relate to the GUT.

> All the fancy mathematical theories that physicists have pursued in recent years – quantum field theories, gauge theories, superstring theories – are formulated within the framework of quantum mechanics. If there is anything in our present understanding of matter likely to survive in a final theory, it is quantum mechanics. (Weinberg, 1993, 65-66)

Weinberg was not referring to Bohm's theory but to the standard quantum mechanics that we know and that is taught from the textbooks I have mentioned. Further:

> Quantum mechanics may survive not merely as an approximation to a deeper truth, in the way that Newton's theory of gravitation survives as an approximation to Einstein's general theory of relativity, but as a precisely valid feature of the final theory. (Weinberg, 1993, 89)

For Einstein indeterminacy was an offense to science and he never accepted quantum theory. But he still had the following to say regarding Bohmian quantum mechanics:

> I reject … the assumption that a rigid coupling exists between parts of a system spatially arbitrarily far apart from each other (instantaneous action at a distance, which does not decrease with increasing distance) (In Cushing, 1994, 147)

It is also noteworthy that Weinberg nowhere mentions Bohm's theory or the pilot wave in the discussion about the future GUT which leads one to conclude that Bohm is irrelevant for GUT research today. The battle over whether indeterminacy exists or not was fought and decided 50 years ago and the understanding of indeterminacy has been refined in the years since. If there was hope that Bohmian quantum mechanics would solve the problem of indeterminacy then that hope has been given up by now. It is not up to theologians and philosophers to decide about the nature of quantum theory. The discussion about the exact deterministic nature of quantum mechanics needs to be fought in the journals of physics and not in philosophy and theology.

Hodgson argues that quantum mechanics could have been established as a deterministic theory based on the pilot wave theory of Broglie and Bohm. But Niels Bohr singlehandedly convinced physicists to accept indeterminacy (Hodgson, 2000, 506) and as a consequence the Copenhagen interpretation was "uncritically accepted by most physicists" (506).

The history shows that there has been controversial discussion on the subject of indeterminacy as mentioned above and as also evident even from James Cushing's (1994) book on the history of the debate. There is no question that the Copenhagen interpretation has been the subject of a critical evaluation over and over again. Given that Bohmian quantum mechanics cannot solve the problem of determining the position and the velocity of the electron (Hodgson, 2000, 510) it is not clear what Bohmian quantum mechanics would add except the idea that in theory we have determinism. The fact that it is widely ignored by scientists (see also Cushing) means that the concepts of Bohmian quantum mechanics are irrelevant to quantum mechanics. If the pilot wave had added to our understanding then it would have been used and been mentioned as a useful alternative in textbooks such as Peebles or mentioned as possible contribution to a Grand Unified Theory. Quantum mechanics is well established and textbooks on the basics of quantum mechanics from 40 years ago are still usable today. The theory of quantum mechanics is stable. The 50-year history of unfruitful research of advocates of the pilot wave theory on the sidelines is evidence that leads one to the inevitable conclusion that Bohmian quantum mechanics is only of historical interest.

It is simply not credible today to use a deterministic nature of quantum mechanics as a basis for a scientific discussion. The publication of Peter Hodgson's argument arguing physics favoring Bohmian concepts and understanding in a journal of theology instead of physics is also an indicator of the credibility issues that the theory faces among scientists. I am not a physicist and so I will only pick up one issue brought up by Hodgson on page 509. Hodgson argues essentially that the position and velocity of a particle can be established more accurately than allowed by Heisenberg's uncertainty principle if one allows assumptions about the past history of a particle. Essentially two measurements are performed on the same particle at two points in time and space. Such assumptions are problematic since one is neither assured to have the same particle (particles are indistinguishable see Eisberg and Resnick 1974, 329). The availability of information about the path taken will influence the very outcome of the experiment (Grangier, Roger and Aspect experiment see Greenstein and Zajonc 35-42). These problems are not discussed by Hodgson but the inference is drawn that one can establish the position and momentum to a degree violating Heisenberg's Uncertainty relation.

3.4 Indeterminism and Classic Physics

In classical physics we can determine accurately the position and velocity of a billiard ball, for example. But our control over matter is still fairly limited:

> Classical physics is also indeterminate in a sense. … If we knew the position and the velocity of every particle in the world, … we could predict exactly what would happen. …. Suppose, however, that we have a finite accuracy and do not know exactly where just one atom is say to one part in a billion. Then as it goes along it hits another atom, and because we did not know the position better than to one part in a billion, we find an even larger error in the position after the collision. And that is amplified of course, in the next collision, so that if we start with only a tiny error it rapidly magnifies to a very great uncertainty. … Given an arbitrary accuracy, no matter how precise, one can find a time long enough that we cannot make predictions valid for that long a time. … Already in classical mechanics there was indeterminability from a practical point of view." (Feynman, 1965, 2-10)

The indeterminability here seems to be a epistemological problem at first. Would we know the accurate details on all those billiard balls to an arbitrary degree then we would just face the computational challenge of computing the future path of the billiard ball. But then all those billiard balls are composed of quantum systems that are fluctuating. Maybe these fluctuations are only extremely minimal but the collisions will vastly amplify these minor fluctuations. Ultimately we have to consider the basic nature of matter. All authors state that there are indeterminacies or random fluctuations introduced by the Q potential in Bohmian mechanics. Given indeterminability of this form it is easy to move from epistemological indeterminacy to ontological determinacy or the Q potential determined form of randomness according to ones beliefs in the indeterministic nature of Quantum mechanics. There is no difference in the effect that this state of affairs has on the reality we experience whatever we call it. Since I am a pragmatist I frequently have difficulties discerning between the two forms of indeterminacy. For all practical purpose they are the same.

Determinism can only be exercised in a very limited real. It is an idealization that is helpful to model behavior of controlled system and matter. It is an abstraction and therefore a simplification necessary to be able to gain the ability to predict future events. Determinism is elusive even in classic mechanics.

4 Collapse and Measurement

4.1 What is measurement or quantum collapse?

John Polkinghorne has written a short book on *The Quantum World* (1984), which has been widely used in the area of divine action, and his views on quantum mechanics have set the tone in the field. Chapter 6 discusses wave function collapse.

Collapse happens when one of multiple potentialities (represented by multiple components of the wave functions) in a quantum system is actualized. At that point the multiple potentialities vanish and one potentiality is selected. Polkinghorne refers to this event as “fixing” (Polkinghorne, 1984, 60). Commonly “fixing” takes place when a measurement is performed. Measurement is when an instrument (macroscopic) interacts with a quantum system in order to quantify a value. Typically there is a dial on the instrument that shows the quantity measured. In measurement a definite result is obtained for a value. Therefore multiple potentialities vanish and are replaced with the obtained result.

Saunders develops a similar notion of an *event* in quantum mechanics as the selection of one result from among multiple potentialities described by the wave function for a quantum system (Saunders, 2000, 528), which is simply the same as the above but without a measurement device. An event happens if one potentiality is realized by collapse.

The problem with collapse is that it is not clear when this happens even if we try to “measure” a single quantum (Tracy in Russell 2001, 254 / Greenstein and Zajonc, 1997, 190). The individual quantum that is supposed to be measured is in an entangled state with the quantum particles of the measurement device. The measurement device itself is in a quantum-entangled state with the optical nerves of the scientist observing the instrument and so on. The wave function gets more and more entangled with other components as we try to describe more of the measurement apparatus using quantum theory. We can only be sure that collapse has happened when our consciousness recognizes an event (Polkinghorne, 1984, 62). Collapse could happen anywhere in the chain. This also begs the question if collapse can happen without us observing.

4.2 Locating Collapse

Polkinghorne describes 4 solutions to the problem of how a quantum system is getting in to a definite state.

The first possibility is to assume that the wave function is just a description of the knowledge of the observer of the situation. Through measurement the knowledge of the quantum system has changed. More is known about the system and therefore the description of the system is different. Collapse is about a change of my knowledge about the system. But taking such an approach would mean to demote physics to a branch of psychology and deny the physical reality of the chain of consequences linking the quantum under observation to the observer (63).

The second possibility is that collapse happens when the system gets large. Classic measurement instruments are large compared to the quantum system under investigation. Those instruments have been designed to act with Newtonian dependability and are therefore subject to classical physics. In our experience the instrument registers a distinct value and not a probability. The classic understanding of quantum mechanics is that collapse must have happened at this stage.

The question arises what constitutes a measurement device. How big does it have to be? It is not clear how large would be sufficient for collapse to take place. Somewhere it seems classical behavior has to set in though (63).

The measurement instrument itself ultimately consists of quantum particles that are governed by quantum mechanics. The measurement instrument could be described by a wave function and seen to be in entanglement with the quantum system under investigation. So the conceptualization of the measurement apparatus as classic seems to be arbitrary. The boundary between classic and quantum behavior and therefore also the place where collapse happens in the chain seems to be artificially imposed (64).

The third possibility is that the observer causes collapse We know that measurement/collapse has happened when we consciously recognize an event. At that point or before the wave function describing multiple potentialities must have collapsed into one outcome otherwise we would need to have the ability to recognize potentialities instead of actual collapsed systems as we know we do. One approach could be to see collapse happen at the very end of the chain. The human mind could be seen as an agent that causes collapse of the wave function (Polkinghorne, 1984, 65; Butterfield in Russell 2001, 122).

There is something very unattractive about this solution because it is highly anthropocentric (Polkinghorne, 1984, 65). Do only humans have the ability to cause collapse? And what happened before humans were around to do the collapsing jobs?

The last possibility is a many-worlds scenario. The many-worlds approach simply affirms that all potentialities are realized. The universe branches into as many distinct realities as necessary to realize all of the possibilities. The distinct realities cannot communicate with one another after the branching. Polkinghorne rejects the many-worlds approach on the grounds that it is an uneconomical explanation (67-68).

In my opinion the major issue with the many-worlds theory is that it does not solve the problem of quantum collapse. The observer will end up in one of these universes and still has a unique history that can be traced back and that needs an explanation. The question where in the chain the collapse happened is not resolved by the many-worlds approach.

4.3 "Picking" one possibility of how and when collapse happens

Polkinghorne resolves the question about when collapse occurs in the following way:

> Does the fixity on a particular occasion set in as a purely mental act of knowledge? At a transition from small to large physical systems? At the interface of matter and mind that we call consciousness? In one of the many subsequent worlds into which the universe has divided itself? Of the suggestions that we have canvassed the one that seems to be the most

> promising is that which points to the emergence of the classical measuring instruments from a quantum mechanical substrate, even if the mode and consistency of this happening is harder to comprehend that Copenhagen orthodoxy is willing to recognize." (Polkinghorne, 1984, 68).

The choice of what measurement is and where collapse happens is to a large extent a metaphysical non-scientific choice. Polkinghorne as a scientist decides to define measurement and collapse in terms of his instruments in the laboratory. What we know is that collapse has taken place when it arrives at the level of our consciousness because we only know of one outcome and not of multiple (62).

Depending on the size of the quantum system effects of collapse can have a smaller or bigger impact on the environment. If a single quantum collapses by itself all alone then the effect is minuscule. But if a quantum system that is entangled with a measurement device collapses a macroscopic effect on the dial is accomplished. The very fact that we can measure singular quantum quantities means that we have the abilities to produce an entanglement to amply the effects so that they affect macroscopic visible things like a dial.[1]

Pokinghorne's work is useful for the clarification of collapse and measurement. After we have clarified some issues involved with measurement and collapse we can now apply this to the discussion in *Zygon*.

4.4 God and collapse

Saunders proposes that God could be seen also as an agent causing collapse or measurement: "If God acts consistently with the principles of quantum mechanics, by

[1] See GFR Ellis work in Russell, 2001 for an overview of how quantum effects can influence the macro world.

exploiting the indeterminism of the orthodox interpretation, then these actions can take place only by some type of measurement interaction" (530). Some kind of measurement needs to happen and God would need to have something to do with this collapse. Measurement is understood here not as an instrument measuring a quantum quantity but as simply a collapse happening for some unknown reason. The question of what interacts how is left up in the air. Implicit in Saunders description is also the assumption that God is an external autonomous entity that interacts with the universe.

Saunders then concludes that the Heisenberg Uncertainty principle does not provide enough freedom to avoid a deterministic universe (530). A discussion of the scope of quantum systems in particular entangled system is missing. Saunders seems to believe that collapse happens on the scale of an individual quantum and therefore what could be affected by measurement is a very minimal change. That is not the case as discussed earlier. The measurement device itself is an amplifier and the very fact that it displays a measurement means that the value measured was able to affect a pointer on a dial. This means that the uncertainty principle *does* provide enough freedom to have macroscopic effects. Saunders argument is invalid.

Raymond Chiao discusses quantum entanglements of photons exhibiting non-local effects (Russel, 2001, 36). These quantum entanglements are collapsed by an observer that is potentially billions of light-years away on a distant planet. The quantum entanglements mentioned not only span large distances but also sizeable amounts of time since light billions of light years away will take billions of light years to get to the observer. The collapse of quantum system can involve large distances as well as large time frames.

The wave functions can not only be used to describe individual quantum particles but can also be applied to objects of a larger scale as done by Polkinghorne in the previous section. Wojciech Zurek argues that there is “no indication of a border between quantum and classical behavior where equation 1 [the Schroedinger equation] fails” (Zureck, 1991, 36). Greenstein and Zajonc discuss examples of quantum behavior becoming evident at the macro level such as superconductivity, the Josephson effect and SQUIDS (Greenstein and Zajonc, 1997, 171-179).

Quantum effects are typically destroyed in macroscopic systems through random influences from the environment termed decoherence (Zurek, 1991, 37). Quantum systems need to be isolated to show quantum behavior. But these influences are “random” and therefore indeterminate as well. It could just happen that these influences stop in a certain environment to allow a quantum effect to surface. Where these quantum effects stop cannot be accurately defined.

If we would take the extreme position that the human observer effects the collapse then observing a dial of a measurement apparatus and therefore collapsing the finger on the dial to a certain setting will determine the state of countless quanta. The conclusion that there is not enough freedom is not warranted at all.

The paradox of Schroedinger’s cat is a classic example that would clearly show the problem with Saunder’s line of reasoning. It is true that a single quantum event triggers the event. One interpretation of what happens would be that the observation of the cat will determine the status of the large set of quanta involved and collapse them to a definite state so that the cat is either alive or dead (see also Murphy, 1995, 356-357).

4.5 Energy and Interaction in Collapse

The wave function, if seen as describing alternative outcomes, can be conceptualized as a sum over wave functions describing one of the different outcomes that could take place. The wave functions for each of the different types of outcome describe all aspects of the scenario and therefore also include all information about energy exchanges and other physical forces that matter for the situation.

The "decision" regarding which scenario is realized in collapse cannot involve any energies since these are already described by the wave function components. Collapse does therefore not involve a need for energy or any physical force.

5 Saunders Four possible means of divine action

Saunders discusses four potential possibilities of divine influence over quantum mechanics (Saunders, 2000).

5.1 God alters the wave function between measurements (536)

The wave function is used to deduce what the probabilities of a certain outcome would be. Schroedinger's equation does describe the wave function. Saunders proposes that God changes the wave function so that it includes "as a superposition a new state that God wishes to become a possible outcome of a measurement"(536). As Saunders notes the change introduces an entirely new component and drastically changes the wave function. Changes to the wave function would either be a violation of the laws of quantum theory or it would require God to change reality itself. It would be *interventionist* and all the cited authors evaluated by Saunders explicitly deny that their proposals would change quantum theory.

Adding a new component to the wave function might not guarantee the outcome wanted. It might just shift the potential of the outcome. For this reason the approach is not satisfactory for a theory of divine action.

5.2 God makes his own measurements on a given system (537)

God could use "measurements" on quantum systems to determine outcomes. This means that before we get knowledge of the system it has already a defined outcome. God collapses the potential. Saunders argues that God performing measurement would change the statistical distribution. The argument is that we typically get a statistical distribution when performing repeated measurements of the system. If God would determine the outcome then the statistics of the system would change.

It seems to me that Saunders ignores the fundamental character of divine action. Divine action is not repeatable. Statistics are an average over multiple incidents. If God would act in a regular way with divine action then the statistics would change. A singular divine action in the midst of ideally unlimited measurements that we average about is not noticeable. On the other hand if God would act in a regular way and God's action would be repeatable and consistent in such situations then divine action would be indistinguishable from a law of physics. But that is not what we mean by divine action.

The "experiment" that Saunders envisions is not repeatable nor is a violation of the statistical distribution over the long run possible. God "measuring" Schroedinger's cat and determining the outcome would be a single event. Divine action by its very definition is special action and not repeatable and therefore also not measurable as desired by Saunders to cause a violation of quantum probabilities.

Saunders envisions that something would be needed to cause a collapse and that something would need to cause an interaction. Saunders proposes that “God fundamentally interacts via ‘tentacles’ in creation which are in principle fully observable” (538). If collapse is understood as happening through an instrument as Saunders does here then that is true. We would have to assume that God would need to have a lab, collect the quantum particles whose attitudes need adjustment and subject the quantum particles to his measurement device.

Collapse as understood by Butterfield (in Russell, 2001, 122) and others, which is the selection of one state of a series of possible quantum mechanical outcomes, is not something that requires interaction. The interactions involving “something” that exchanges energy etc are described by the wave function (see also above). One of the options would be that a human consciousness causes one of the possible interactions to materialize. Collapse occurs without any discernable physical force involved in the choice of the quantum outcome. Collapse also “does not mean that some physical entity has discontinuously changed” (Peebles, 1992, 236).

God collapsing quantum systems is not really useful, as noted by Saunders (537), since a measurement would not allow God to determine a specific outcome. God would have to take whatever the outcome would be. But that is not what is proposed by the proponents of quantum divine action. What is proposed is that God can determine the outcome. See the fourth possibility for a working approach.

5.3 God alters the probability of obtaining a particular result (538)

God alters the probability of the outcome. Ideally God would change one outcome to a certainty. The problem with Saunders third option is that probabilities are calculated based on the wave function. Therefore, this proposal approach can only be different from the first scenario, if we can separate the probabilities from the wave function. God must have the ability to ignore the wave function and set a probability for the outcome. This would be God simply ignoring the regularities of quantum theory. The comments for the first scenario apply.

5.4 God controls the outcome of measurement (539)

God not only causes measurement but also controls the outcome of that measurement. One of the deficiencies of the earlier proposal has been that the outcome is not guaranteed.

Saunders objects that this would require a revision of the "ontological nature of the measurement probabilities" (539). The conception of measurement probabilities as being of an ontological nature is something that I have difficulties with. Probabilities only give likelihoods. I am not sure how I would understand likelihoods as having a reality of their own.

As noted earlier measurement (collapse) can be understood to have occurred in a variety of ways. One is when a human consciousness recognizes that a certain event has taken place. No physical effort is required for that. God's consciousness could work in a similar way. We are here in the area of indeterminacy and collapse/measurement.

My theory is that God's superior consciousness can determine the outcome of a collapse. Human consciousness can just cause one out of many outcomes to happen without the human having the ability to select an outcome. God can select one that he likes.

Saunders agrees that such an approach does not present any specific problems (539). The issues that Saunders has with such a conception are largely philosophic. We need to accept that God's action is intermittent and that God does not influence every quantum event. That is just what is needed because it allows making a distinction between divine action and the regular operation of matter in the universe.

If we accept the intermittent nature of God's action then "[God] acts by determining certain quantum measurements, and the probabilities predicted by the theory include these divinely determined quantum measurements" (539). Saunders claims that God has to preserve the quantum statistics. Statistics are predicting probabilities and if one series of measurement is untypical then a statistical prediction for a situation has not been violated. Nothing is wrong with such an event.

Later Saunders again claims that divine action has to "remain within the regularity of physics" (540). Quantum mechanics has shown that the higher physical laws of physics are of a statistical nature (see above and Tracy, 2000, 897). As long as the fundamental laws of quantum mechanics are adhered to, the higher laws can be violated without being scientifically incorrect.

The fourth option by Saunders is the only one that preserves the lawful relationships that are described in quantum mechanics (Tracy, 2000, 897)

6 Conclusion

The idea that God causes collapse has been expressed elsewhere before and that proposal seems to be a very promising approach to divine action. Saunder's article is very helpful to clarify possible approaches to divine action given its candid evaluations.

The idea of quantum divine action through God performing collapse is in harmony with what we know about quantum mechanics. It is possible because of our inability to describe when exactly the collapse of the wave function happens. If we would know and determine what a quantum event is then there would not be freedom anymore for God to collapse when he likes. The analogy to human consciousness doing the collapse is another nice feature of this solution. One could speculate that God has a consciousness so he is like us and is also collapsing as he looks at the universe. This is of course a very anthropocentric view. One could even fantasize further and take the leap to assume that God has a superior consciousness and can actively select one of the potential outcomes, which makes him divine compared to us.

All the ways of trying to prove that quantum theory is deterministic (such as Bohm's interpretation of quantum mechanics) are not credible to me given the consensus in physics about the indeterminate nature of quantum mechanics and the disuse of the pilot wave or Bohmian theory. The proof for the ontological nature of indeterminism as implied by the Copenhagen interpretation (no regularity) is not possible since this would be proving a negative: Bohmian quantum theory is consistent with our observations in quantum mechanics but cannot be proven since it assumes the quantum potential Q that is influence in a non-local way by all particles of the universe. The situation would change for me if I would see a discussion or adoption of leading physicists of Bohmian quantum mechanics. My impression is that Bohmian quantum mechanics is not taken earnest by physicists. The use of Bohmian quantum mechanics in an argument over divine action is therefore counterproductive and might cause scientists not to look at the work of theologians and philosophers in science and religion. The argument of Bohm vs. Copenhagen would better be settled in physics rather than in philosophy or theology.

The speculation here about how God could act is scientifically unprovable since it sneaks intoan area of quantum mechanics not accessible to us, which is indeterminacy and how and when wave function collapse. Both of these are fundamental features of quantum mechanics that are not likely to change and which have been well established. Weinberg even expects quantum mechanics to be a corner stone of a future Grand Unified Theory should it come to pass.

It is sufficient for theology because it allows large-scale action. The scientific unprovability moves the acceptance of this idea into the area of faith. What is behind indeterminacy and quantum collapse? For the some there is God. For the agnostic like Monod there is just chance.

Saunders asks the question "Does God Cheat at Dice?" We should reformulate that to a not so provocative question: Can God determine the outcome of throwing a dice? The answer is: Yes, of course he can.

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