Quantum Theology beyond Copenhagen

with Mark Harris, "Quantum Theology beyond Copenhagen: Taking Fundamentalism Literally"; Shaun C. Henson, "What Makes a Quantum Physics Belief Believable? Many-Worlds among Six Impossible Things before Breakfast"; Emily Qureshi-Hurst, "The Many Worries of Many Worlds"; Elise Crull, "Interpretation Neutrality for Quantum Theology"; Wilson C. K. Poon and Tom C. B. McLeish, "Is There a Distinctive Quantum Theology?"; and Ernest L. Simmons, "The Entangled Trinity, Quantum Biology, and Deep Incarnation."

IS THERE A DISTINCTIVE QUANTUM THEOLOGY?

by Wilson C. K. Poon and Tom C. B. McLeish

Abstract. Quantum mechanics (QM) is a favorite area of physics to feature in "science and religion" discussions. We argue that this is at least partly because the arcane results of QM can be deployed to make big theological claims by the linguistic sleight of hand of "register switching"—sliding imperceptibly from technical into everyday language using the same vocabulary. We clarify the discussion by deploying the formal mapping of QM into classical statistical mechanics (CSM) via the mathematical device of "Wick rotation." This equivalence between QM and CSM suggests caution in claiming distinctiveness for quantum theologizing. After outlining two areas in which quantum insights nevertheless resonate with longstanding themes in theological reflection (hiddenness and visualizability), we suggest that both QM and CSM point to a theology of science in which scientists participate in the divine gaze on creation as *imago Dei*.

Keywords: contemplation; hiddenness; quantum mechanics; science; statistical mechanics; theology; visualizability

Introduction

Quantum mechanics (QM) has long fascinated people of faith who think about science's implications for religious belief, whether lay believers or theologians. In its hold on their imagination, QM outcompetes even Einstein's theories of relativity, which form the second component of the early-twentieth-century tripartite revolution in physics. The third

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component, classical statistical mechanics (CSM), seldom receives comparable attention except in specialist literature. In the world of "physics and religion," quantum theologizing reigns supreme.[1] Indeed, as the centenary of Heisenberg's 1927 Uncertainty Principle approaches, interest in quantum theologizing may be accelerating—witness the symposium behind the present volume. A spate of books since the 1990s tells the same story.[2] There is even a play, "God's Dice" (2019) written by atheist comedian David Baddiel about a quantum physicist finding God. Evidence for a renaissance in quantum theologizing also comes from a 2005 topical public lecture by the then Gresham Professor of Divinity, Keith Ward, on "Religion and the quantum world." No wonder Mark Vernon (2013) says in the *Church Times* (italics ours), "The weird and wonderful world of quantum physics is becoming a spiritual resource, or so an *increasing* number of people claim."

Our first objective is to understand this popularity of quantum theologizing. Drawing on quantum theologies from the beginning of QM and more recent literature, we tell a cautionary tale about a kind of linguistic sleight of hand that spawns a style of facile theologizing that obscures the real issues. We next turn to CSM. In an historical episode that is little, if at all, acknowledged in the science-and-religion literature, CSM was unified with quantum field theory in the 1970s. The resulting statistical field theory (SFT) has revolutionized the treatment of everything from the quark-gluon soup through high-temperature superconductors to polymers. We explain why bringing CSM in from the cold *via* SFT casts considerable doubt on claims of distinctive quantum contributions to theological understanding. Nevertheless, there are resonances between QM and well-known themes in theology; we outline two, before moving on to suggest why both QM and CSM point toward a participatory theology of science.

Register Switching in Quantum Theologizing

One of the earliest (and to date most sustained) attempts at quantum theologizing was from the Quaker Sir Arthur Eddington. After discussing QM in chapters IX to XII of his 1927 Edinburgh Gifford Lectures, Eddington gathers up the threads in Chapter XIII: "To put the conclusion crudely – the stuff of the world is mind-stuff," and "the substratum of everything is of mental character." He concludes that "[t]his view … perhaps relieves to some extent a tension between science and religion." (Eddington 1928, 276, 281) These lectures hit home for many. Richard Conn Henry, a retired Canadian physics professor tells us that (italics original), "until quite recently, [I have] always been an atheist materialist." However, after reading Eddington as a teenager and through forty subsequent years of teaching physics, Henry "gradually … realize[d] what

Eddington realized at once: one *must* reject materialism, as *there is no material*." The result is that "in 2004 – to my utter astonishment – … I turned into a theist. I became religious *solely* through study of physics." (Henry 2007, vi)

Such bold claims for the theological impact of QM are made not just by physicists. In his Gresham Lecture,[3] Keith Ward (2015) claims that "materialism has become quite a respectable thing to think [from Newton to Darwin], until you get to the twentieth century and quantum physics, and that destroys materialism completely. It's no longer possible intellectually and respectably to be a materialist after the rise of quantum physics." Instead, QM supports idealism (mind over matter), because it gives "the observer" a central role. Ward goes on to argue that Heisenberg's Uncertainty Principle decisively destroys determinism and brings back free will, while "quantum entanglement" destroys reductionism and replaces it by holism, because it shows that "everything is connected with everything else." He concludes, "So, it's very hard for a quantum physicist not to believe in a God, and the ones who don't believe in God tend to say, 'I'm not going to deal with these theories at all. I'm just going to do the experiments.' That's always a possibility, but it's a betrayal of the scientific quest to understand what the world is really like. So, if some people are uncomfortable about God having become more important, that's tough, because that's the way quantum physics is."

Even a cursory internet search shows how common such bold claims for QM on behalf of religious belief are (e.g., Thuraisingham 2019; Beliefnet 2022). Some contemporary commentators have obliquely registered their unease at this style of quantum theologizing. Thus, Mark Vernon (2013) counsels in the title of his piece in the *Church Times* (italics ours), "Quantum spirituality: *tread softly*." He goes on to invoke John Polkinghorne (again, italics ours), "Physics is showing the world to be both more supple and subtle, *but you need to be careful*." To understand what it may mean to "tread softly" in a "careful" approach to quantum god-talk, we analyze an instance where this advice is not heeded, how Keith Ward moves from QM to idealism and holism in his Gresham lecture.

Ward first explains, correctly, how entities in QM "are actually different when they're being observed and when they're not being observed."[4] In physics, saying that something is "being observed" simply means that a measurement has been registered by some apparatus. For an electron, this may be the "clicking" of a deliberately deployed Geiger counter, or a naturally occurring piece of fortuitously located "cathodoluminescent" mineral emitting a photon. Then, after explaining that an electron's wave function tells us about the probability of various observational outcomes, Ward concludes that electrons "only exist when you observe them." Note how Ward has slipped from the passive "being observed," with an unstated, "implied subject" that could have been a Geiger counter, to the active "you observe," with a thinly veiled human subject. Before long, the question is raised, "Where is the electron when we're not looking at it?" "To observe" has now become "to look," and the audience has joined the lecturer as the "we" who engage in the action. After expounding Bishop Berkeley's idealism, Ward tells us that "[electrons] only exist if you're looking at them … which collapses the probability wave into a particle. But then you gotta look at it to see that. So, if you're not looking, electrons don't exist; only probability waves exist."

At the end of this sequence of linguistic somersaults, "observations" are now definitely carried out by human "observers" who "look." Ergo, "[t]he whole of the material world is a construct of the mind. If this is right, materialism is not only dead, it's completely falsified." After pressing home this vindication of idealism, Ward concludes, "What do you make of that? … Well, this shows that the whole reality is a construct of mind. It's constructed by mind. What mind could it be, then? The mind of God …," *quod erat demonstrandum*!

What allows Ward to fast-track from QM to idealism is "register" switching (Agah 2004). Loosely, a "register" is a distinctive vocabulary for a particular context; it is distinguished from "style," which is more concerned with grammar and higher-order structures. Crucially, one may sometimes switch register *without* any obvious switching of vocabulary. In these situations, unless great care is taken, both writer/speaker and reader/listener may get confused by the barely perceptible register change. This danger is very real, for example, in ecology, where everyday words like "habitat" have been coopted to have precise technical meanings (Adams 1997). On the other hand, register switching can generate humor. Anyone who chuckles at the headline "DOCTOR TESTIFIES IN HORSE SUIT" has succeeded in switching between legal and everyday register on seeing the word "suit." (Bucaria 2004)

Ecologists borrow everyday words because they study entities that are often very familiar to the lay public. QM borrows everyday words for the opposite reason. Its abstract, mathematical content means that coopting everyday words is really the only option (unless, as Eddington (1948, 291) suggested, tongue in cheek, one borrows words from Lewis Carroll's nonsense poem *Jabberwocky*).[5] Almost imperceptible register switching is therefore a real temptation in speaking about QM. In Ward's fast-track demolition of materialism in QM's name, he starts by using the verb "to observe" ("being observed") in a sense that is consistent with the professional register of physicists and philosophers, for whom this verb and its cognate noun ("observation") is almost equivalent to the pair "to measure/measurement." However, because QM has borrowed everyday words as jargon, Ward can slide imperceptibly from "observation" to talking about an "observer" who is "looking," the latter being a verb that is almost never used in scientific register. By now, his audience is thinking not about inanimate measurement apparatus, but sentient humans, paving the way for Ward's *coup de grâce* to materialism: "this shows that the whole reality is a construct of mind. It's constructed by mind. … The mind of God."

Ward (2015) similarly fast-tracks from quantum entanglement to holism:

> Once two elementary particles have interacted … [t]hey remain entangled wherever they are … You can put this picturesquely but not inaccurately by saying everything that happens anywhere in the universe affects you. So, if a photon comes into existence a billion light years from here it affects you. Fortunately, you won't notice. But you are connected with it. … Interconnectedness, we're all connected. But it's actually part of quantum mechanics and an essential part of it.

It is because "entangle/entanglement" are everyday words that Ward can slide imperceptibly (but, despite his claim to the contrary, inaccurately) from a professional to an everyday register, and thence to a thumping Q.E.D. for holism. If the argument had been couched in the technical jargon of "many-particle quantum states" or "product Hilbert spaces," it would have been clear that the photon materializing a billion light years from "you" is not entangled with "you," because "you" and it have not interacted in the first place, and Ward's "argument" is actually a case of *demonstrandum non demonstratur*. Ward is by no means unique in register switching when discussing quantum entanglement. An author declares in *Christianity Today*, "Subatomic particles are not the only things that are entangled in our universe. So are we. We are entangled with one another …" (Looper 2017) Both claims in this quotation about entanglement are correct, but they deploy "entangled" in professional and everyday register respectively. The first therefore does *not* support the second, as the writer no doubt intended that it should.

Physicists warn students repeatedly against confusing professional with everyday register. Thus, an "observation" in relativity theory simply means a record of the space-time coordinates of an "event," and does not involve anyone "looking." Sober quantum theologians have similarly warned their readers that "the 'involvement of the observer' (in QM) refers to *observation-processes* and not to mental states as such." (Barbour [1966] 1971, 287) Therefore, a facile, fast-track passage from QM to idealism that relies on sliding from professional to everyday register is a case of "jargon abuse" (Martinez 2020). Notably, an early critic of Eddington's book already directed her ire against the "casual misuse it made of everyday language, and … the much larger implications Eddington encouraged his readers to draw from it."[6]

In sum, the ubiquity of everyday words in quantum jargon facilitates the casual use of QM to make big theological claims. Once someone of the authority of Eddington has started the process, it became a case of "free for all." The use of everyday words in QM is not, of course, Eddington's fault, because QM *is* arcane, even by the standards of theoretical physics. The trouble is that, as Bertrand Russell complains (and we agree), register switching enables "Eddington [to expound] … recent development [in physics] in a manner which conveys more of it to the nonmathematical reader than I should have supposed possible." (Russell [1931] 1962, 81, 92)

Others were more careful. Niels Bohr warned that "words like phenomena and observation … are … used [by physicists] in a way incompatible with common language and practical definition," and so "are apt to cause confusion" (Bohr 1958, 73). Nevertheless, one wonders whether he and others of his era such as Erwin Schrödinger (1935), who coined quantum "entanglement," have thought through the potential dangers of register switching. This situation recalls Charles Darwin's *Origin of Species*. Literary scholar Gillian Beer, who describes what we call "register switching" as "metaphors … overturn[ing] the bounds of meaning assigned to them" in a professional register when they are redeployed in a popular register (Beer 2009, 50–51), is of the opinion that "it may be [Darwin's] *disregard* of the potential sociological applications of many of his terms [= register switching] which makes them so uninhibitedly available for application" in sundry fields outside biology.

Quantum theologizing that relies on facile register switching brings religious belief into disrepute. It is unconvincing for most physicists, who spend much effort warning students against precisely such register switching. It is also unconvincing for philosophers. Susan Stebbing ([1937] 1944, 211–212), an atheist, ends her critique of Eddington the Quaker with this devastating observation:

> Surely a view that finds a place for Mind in the universe only after the principle of uncertainty has been discovered or after abstruse physical speculations … is not a view that should commend itself to the earnest seeker after God, especially if that seeker be a Christian. At least, I should have thought not, were it not that Christian apologists have been so eager to wait upon the pronouncements of the physicists, so thankful to be assured that we put into Nature the laws we profess to discover …

Quantum theologizing need no rely on casual register switching. Other articles in this volume offer examples, such as the discussion by Qureshi-Hurst (2023) of the so-called "many-worlds interpretation." However, space precludes engagement with such treatments.

CSM and Putative Quantum Uniqueness

Claims of victory for idealism over materialism or holism over reductionism on behalf of QM are often accompanied by the suggestion, for example, by Ward (2015) in his Gresham lecture, that QM is uniquely able to deliver this because it transcends the classical mechanics of either Newton or Einstein. Irrespective of whether QM indeed supports idealism or holism, the claim of quantum uniqueness needs scrutiny in the light of an area of classical physics that is seldom, if ever, discussed in the science and religion literature: CSM. Since the 1970s, physicists have known of a striking formal mapping whereby every problem in QM corresponds mathematically to a different one in statistical physics. Furthermore, CSM has long given an essential role to sentient observers in creating models of the world in the definition of "entropy," one of its core quantities, quite independently of "observers" in QM. Any claim of putative quantum uniqueness must therefore be examined in the light of these developments.

Mapping QM to CSM

Beginning in the 1970s, physicists began to realize that apparently unrelated but equally intractable difficulties in quantum field theory and in CSM could be solved together using a surprising mathematical trick known as the "Wick rotation" (Fraser 2020). To understand the resulting unification, statistical field theory, we need the idea of a very basic quantity in QM, the *propagator*. In QM, the square of the propagator[7] gives the probability that a particle, starting at some point, should arrive at another point R away after time t. With the propagator in hand one can calculate predictions for any observable quantity modelled. Feynman found an appealing way to obtain the *quantum* propagator by performing a sum over all possible *classical* paths between these points, each path mathematically weighted by a quantity (technically, a "phase factor") that involves an exponential function of $t/\hbar$, where $\hbar$ is Planck's constant divided by 2π. Mathematically, the quantum propagator of a particle starting at some arbitrary origin and reaching position R at time τ looks like this

$$\Psi\left(R,\tau\right)=\int\limits_{r(L)=R} D\left[r\left(s\right)\right]e^{\frac{-m}{2}\int_0^\tau\left(\frac{\partial r}{\partial t}\right)^2 d\left(\frac{it}{\hbar}\right)},$$

where the first symbol to the right of the equals sign is a stylized "S" denoting summing (or integrating) over all paths. The important feature for us is the combination $it/\hbar$ in the rightmost bracket, where we find $t/\hbar$ multiplied by the imaginary number $i=\sqrt{-1}$, that is to say, a number whose square is -1. This operation of turning the "real time" into an "imaginary time"[8] is called a Wick *rotation* because in a geometric representation of complex numbers (numbers of the form $x+yi$ where x and y are real numbers) as arrows on a plane, multiplication by i appears as a counter clockwise rotation by 90°.

In CSM, the basic mathematical object is the "partition function," which involves a sum over all possible states of a system held at some fixed temperature T. In the partition function, the temperature occurs in the combination kT, where k is Boltzmann's constant. The analogy between "paths" in QM and "states" in CSM involves substituting $1/kT$ for $it/\hbar$ in the propagator, giving the equation for the partition function in CSM. Symbolically, we have

$$\frac{it}{\hbar} \to \frac{1}{kT}$$

For classical polymers (McLeish 2022), the abstract content of the Wick rotation becomes visualizable. The different states of a polymer, a long-chain molecule, are different configurations of a chain, which, in turn, are the very classical paths summed over in the quantum propagator. They range from the unique configuration of the chain being completely straight, to a multitude of coiled configurations. The partition function sums over all these different "paths." The analogy with QM is completed when positions along the path map to corresponding imaginary times in the quantum propagator. The set of paths is representatively "explored" by a polymer molecule dynamically through random thermal motions—a physical process analogous to the entirely mathematical quantum sum, which has no physical interpretation (the often-used description "the particle goes along every path at once" does not bear up to scrutiny). When a system is in thermal equilibrium (= macroscopically homogeneous and unchanging with time), the weighting of these paths, worked out by Ludwig Boltzmann and Josiah Willard Gibbs (Baierlein 1971), is controlled by the temperature through an exponential function of $1/kT$. A century later, Sam Edwards in the UK and Pierre-Gilles de Gennes in France first exploited this "trick" and opened up a new era for polymer physics, and earned de Gennes a Nobel Prize in 1991.

Many more (less transparent and visually striking) examples of such QM-CSM correspondence exist. The polymer case illustrates an important dissimilarity in the physics of the correspondence, which is that time-dependent processes in the QM realm map into thermal equilibrium (and so time-independent) systems in the CSM realm. Philosophical responses to this disjuncture differ widely. Fraser (2020) deduces that the Wick rotation is purely formal, implying nothing for the way the universe is. At the other end of this hermeneutical spectrum, Polyakov (1987), the leading field-theorist, conjectured that the meaning of the QM particle-CSM polymer correspondence arises "from the deep structure of space-time."

The theological implications of this QM-CSM correspondence have been little discussed to date. To our minds, it minimally implies that one needs to be very careful in claiming any kind of unique *quantum* holism.

Technically, using Wick rotation, a path-summing quantum system used to demonstrate entanglement/holism can be turned into a statistical mechanical state-summing system that, at least formally, possesses the same degree of entanglement/holism. More generally, there is a large literature (Gibb, Hendry and Lancaster 2019) discussing emergence and top-down causation that points to a statistical mechanical interconnectedness *without* appealing to any quantum weirdness. The same is true of any other candidate quantum result for theology. Even extremely strange consequences of quantum systems, such as the fractionally charged "anyons" that emerge in very cold many-electron systems confined to surfaces and threaded by magnetic fields, have at least a formal correspondence in the Wick-rotated and corresponding polymer system (McLeish, Lancaster and Pexton 2019). Recent work has pointed out that Long-Range (greater than molecular scale) Topological Order (LRTO, or "entanglement") is a property of both many-particle QM and polymer CSM systems. This presence of irreducible long-range action, also often thought to be a unique feature of QM, furnishes a purely classical example of top-down causation (McLeish, Lancaster and Pexton 2019). This nonreductionist (since nonreducible) structure of some systems has naturally attracted theological comment (McLeish 2019). QM is therefore not unique in several salient ways: holism, irreducibility and top-down causation.

A Role for the Observer?

Theological and philosophical discussions often claim that QM offers a unique role for the observer. With Einstein's relativity, we are introduced to observer-dependent points of view; however, these can be reconciled by properly "transforming between frames of reference," and all observers ultimately agree over all events. In QM, however, it is claimed that the "observer" can determine the outcome of experiments. We have argued that whatever the detailed philosophical meaning of this claim is, it only offers a "fast track to idealism" if one resorts to a linguistic sleight of hand.

On the other hand, it turns out that the description CSM offers of the natural world is indeed dependent on *sentient* observers. This arises from the core CSM concept of entropy, first introduced by Rudolf Clausius and others to describe the efficiency of turning heat flow into work (as in the steam engine), and then formulated statistically by Boltzmann (Baierlein 1971). Most university physics courses (and textbooks) today give the impression that the entropy is an unequivocal property of the physical world. However, Josiah Willard Gibbs, one of the inventors of CSM, has understood from the beginning that the entropy of a system is actually a description of the degree of ignorance that an *observer* entertains vis-à-vis the variables ("degrees of freedom") describing the system (Jaynes 1957; Jaynes

1965; Baierlein 1971). Put another way, the entropy assigned by physical models of thermodynamic systems depends on how coarse- or fine-grained those models are, and is calculated by summing over all possible states of variables whose values are not known, or chosen to be ignored, by the observer constructing the model. It is therefore not surprising that the 1963 Nobel physics laureate Eugene P. Wigner, otherwise famous for his work in QM, once remarked, "Entropy is an anthropomorphic concept" (Jaynes 1965).[9]

As an illustrative example, consider two observers of a quantity of gas. A "fine-grained observer" knows the trajectories and momenta of all the molecules. There are no coarse-grained variables, all values of classical quantities are known at each time; this observer assigns zero entropy to the gas. A second observer has access only to local densities of the gas (defined over some coarse-graining element of very many molecules) and their fluctuations, but not to the position of every particle. This observer does assign a finite entropy to the gas (it takes the form of a weighted sum of the logarithms of the local densities). Crucially, which observer is "correct" depends on what experiments one wants to model. Using the fine-grained entropy will predict the wrong outcomes in an ordinary laboratory experiment in which only the classical thermodynamic variables of pressure, volume, and temperature are accessed. The kind of muddle one could get into when entropy choice and experimental reality "cross wires" is nicely illustrated by colloidal crystallization, a beautiful phenomenon responsible for opalescence. A theory that assigns entropy to a fine-grained observer with access to the world of individual colloids rather than to the coarse-grained world of everyday experiments predicts (wrongly) that colloids do not crystallize (Cates and Vinothan 2015). In this sense, the way CSM describes everything from superconductivity to neutron stars is irreducibly observer dependent.

It might be objected that all that has been claimed is that the values of parameters and quantities differ for *models* of reality simply because of different choices made by the "observers" (defined carefully as those who make those models of the world, presumably after making measurements of it), and that this is a much weaker claim than the observer dependence in QM engendered by "wave function collapse" or whichever interpretation of QM one prefers. However, a moment's reflection will clarify that, in the QM case as well, the "world" or "reality," however realist or idealist a philosophy one holds, is only ever accessed via model-interpreted observation. The nonlocal, top-down, "observer-dependent" nature of QM is no less a property of the model than in CSM. That is what "observer-dependent" means. Yet, this is still contested in QM, but not at all the case in CSM. We know of no other case in physics where the role of the model-choosing sentient physicist is as clearcut and has so far-reaching consequences.

Quantum Resonances

To summarize thus far, we first showed that many attempts to fast-track from QM to certain large theological claims rested on a flimsy foundation of linguistic sleight of hand made possible by the borrowing of everyday vocabulary for quantum jargon. We then discussed two areas (holism and observer participation) where the contribution of QM to theological discussions had been claimed to be distinctive, and found the claims overstated. Nevertheless, we do think that QM can contribute to the ongoing dialogue between science and religion. We now sketch out two such instances vis-à-vis the Judeo-Christian tradition without entering into detailed discussion.

Decoherence and Hiddenness

The everyday world that sentient observers inhabit is not quantum mechanically entangled. In this world, one has to look hard to see evidence of quantum effects. Why? The answer involves "quantum decoherence."

Consider a less emotive version of Schrödinger's cat: a particle that is in a quantum state that can, loosely, be described as "both here (= cat alive) and there (= cat dead)." Formally, we prepare the particle in a quantum state, a mathematical object (a "Hilbert space vector") $|\Psi\rangle$, in which we cannot say for sure whether it is in the vicinity of position (say) $-x_0/2$ or $+x_0/2$, but only give some probability of it being in these two states. This is a wholly quantum mechanical scenario that will not "become classical" until there is a measurement of the particle's position, at which time we can say with certainty whether it is at $+x_0/2$ or $-x_0/2$ ("the cat is dead" or "the cat is alive"). Until then, $|\Psi\rangle$ evolves deterministically according to the time-dependent Schrödinger equation. After an elapse of some time interval Δt since the state $|\Psi\rangle$ was prepared, we can calculate the probability of the particle being at $+x_0/2$ or $-x_0/2$ exactly. Therein lies the conundrum of Schrödinger's cat: we can only give the probability of it being alive or dead, until an observation occurs.

States such as $|\Psi\rangle$ are known as "coherent states." Two subatomic particles are entangled if they are in a coherent state. Nonrelativistic coherent states evolve according to the time-dependent Schrödinger equation, whose solution allows us to calculate the probabilities[10] of obtaining various answers if we were to carry out a measurement at any time, *provided that* the state $|\Psi\rangle$ remains completely isolated. *Any* interaction with the environment will lead, ultimately, to the loss of the state's coherent nature, a process known as decoherence. The typical time for this to occur is the "decoherence time," τ_d.

To estimate τ_d, theorists have considered a simple model in which our 'Schrödinger's particle' interacts with a viscous environment at temperature T. A particle of radius a and mass m moving in such an environment will come to rest after a time of the order $\tau_r \approx m/\eta a$. This so-called "relaxation time" offers a measure of the degree of interaction between the particle and its (viscous) environment. Wojciech Zurek (2002) has shown that the decoherence time of our Schrödinger's particle immersed in a viscous medium is $\tau_d \approx \tau_r \times (\lambda_{\text{th}}/x_0)^2$, that is, the relaxation time multiplied by some number. The number is the square of a ratio of two lengths, the so-called de Broglie thermal wavelength divided by the separation between the two possible positions of the particle in its coherent state.

Quantum effects become important if we confine a particle to a box of the size of the de Broglie wavelength or smaller. For an electron at room temperature, this is about 4 nm. A hydrogen atom is roughly 0.1 nm in diameter, so that we need QM to explain its workings. For an oxygen molecule or a nitrogen molecule at room temperature, λ_{th} is less than 0.02 nm. In the air we breathe, these molecules are separated on average by just over 300 nm, so that they do not confine each other enough to be quantum mechanical: air is a classical gas.

Returning to our model coherent state, for a "Schrödinger particle" of mass $m = 1$ gram at room temperature in a state $|\Psi\rangle$ with $x_0 = 1$ centimeter, the numerical ratio $\tau_d/\tau_r \approx 10^{-40}$. So, even if the interaction of this particle with its environment is so minimal that its relaxation time is of order of the lifetime of the present universe, or $\tau_r \approx 10^{17}$ s, its decoherence time comes out to be of order $\tau_d \approx 10^{-23}$ s, or about one-tenth the lifetime of the Higgs boson. The lesson is that in the macroscopic, centimeter-sized, world, decoherence is essentially instantaneous. For all practical purposes (and considerably beyond), the world we perceive is classical. Cats are never indeterminately alive or dead, whether observed or unobserved.

To see what it would take to make a "Mr Tompkins world"[11] in which quantum weirdness is an everyday occurrence, consider the ratio $(\lambda_{\text{th}}/x_0)^2$. If we want to consider particles separated by a macroscopic distance, say, x_0 of the order of centimeters, then we need the thermal de Broglie wavelength to be also macroscopic to "within shouting distance," say, about a micron (or ten thousandth of a centimeter), which is the length scale of objects just about visible in an optical microscope, so that the multiplier becomes one ten billionth (10^{-8}). Then, a relaxation time τ_r of about a year, which still represents *very* weak interaction with the environment, will translate into a decoherence time of $\tau_d \approx 0.1$ s—not *that* long, but long enough to win or lose an Olympic medal. To change the thermal de Broglie wavelength of a 1 gram particle (still considerably smaller than a cat!) at room temperature from its value in our world of just under 2×10^{-20} cm to one micron, we need Planck's constant to increase by a factor of 10^{18} (a million trillion). However, Planck's constant, the speed of light and the universal gravitational constant together determine three fundamental quantities known as the Planck mass, Planck length and Planck time. The actual observed values of these quantities are "fine tuned" for the emergence of life on earth (Barrow and Tipler 1986, Chapter 5), so that increasing Planck's constant by a factor of a million trillion will rule out any Mr Tompkins to worry about an alternative world in which Schrödinger's cat is an everyday occurrence.[12]

If we want sentient observers, therefore, the "fine tuning" argument dictates that the world they observe, the macroscopic world, *must* be a classical one in which quantum weirdness such as half-live-half-dead cats only occur in science fiction (or certain kinds of quantum theologizing). In the everyday world directly available to our senses, quantum effects rarely "leak through" very occasionally. Magnets constitute an exception: they depend on electrons possessing the property of "spin," which emerges out of Dirac's relativistic QM. Otherwise, quantum weirdness is *necessarily hidden* to macroscopic sentient observers (using this word in the everyday register).

If that is the case, then we may draw a theological analogy. While the Judeo-Christian tradition believes in a God who acts in the (macroscopic) world of flesh and blood, with Christians claiming that the Son of God became "enfleshed" in the person of Jesus (John 1:14), it seems that, paralleling quantum hiddenness, it is necessary for such action to be largely hidden and not easily perceived by casual observers. That is why there are multiple pointers throughout the Old and New Testaments to the *Deus absconditus*, the God who is present through hiddenness, from Moses being only allowed to see YHWH's "back" on Mount Sinai (Exodus 33:18-20) through Isaiah's exclamation that YHWH is a hidden redeemer (Isaiah 45:15) to Jesus' cry of dereliction on the cross (Mark 15:34) and his ascension at which "a cloud hid him" from the sight of the watching apostles (Acts 1:9). From henceforth, the life of the Christian disciple on earth "is hidden with Christ in God" (Col. 3:3). The frustration of living as the *ekklēsia* of such a hidden God comes out into the open in many places throughout the Biblical tradition, for example, in the plea from a prophet to his hidden God, "Oh that thou wouldest rend the heavens … [and] come down" (Isaiah 64:1, KJV).

However, to ask God to render the god-self entirely manifest in a way that will make all talk of the *Deus absconditus* redundant may well be tantamount to asking for an alternative creation that is incompatible with sentient flesh-and-blood creatures, just as asking for quantum-entangled cats entails ruling out any world in which cats of any kind is possible. In contrast to QM, however, Christians claim that when God makes all things new in the *eschaton*, overtly manifest divinity *will* become compatible with sentient creatures. In the new (*kainos*) Jerusalem, "the city has no need of sun or moon to shine on it, for the glory of God is its light, and its lamp is the Lamb" (Rev. 21:23); but that will require a new (*kainos*—new in kind) creation. To pursue this train of thought about quantum and divine hiddenness in detail is, however, beyond our scope.

Visualizability and Speakability

Ever since the beginning, the founders of QM have pondered how they should speak about their creation. For example, Bohr tells us that in QM, we have "a formalism which defies unambiguous expression in words suited to describe classical physical pictures" (Bohn 1958, 40). Bohr here raises not only the issue of the speakability ("words suited to describe") of QM, but also of its visualizability ("physical pictures"). Theological thinkers have, of course, wrestled with the same issues vis-à-vis God for two millennia and more.

Take first the difficulty of speaking about God. Two classic strategies in dealing this difficulty are well illustrated by the opening of a well-known hymn: "Immortal, invisible, God only wise, in light inaccessible hid from our eyes." There are two noteworthy features. First, God is spoken of in *negative* terms as being *im*mortal and *in*visible. This way of god-talking through *denial*, belongs to a long tradition of apophatic theological teaching that recommends the *via negativa* (Turner 1995). Second, there is a paradoxical turn that perhaps familiarity has dulled: "in light … hid from our eyes." Religious poets and theologians have always known that to speak of God necessitates the use of what Bishop Ian Ramsay has called "odd language" involving "logical improprieties," such as "in light … hid from our eyes." Interestingly, Ramsay points out that such linguistic "oddness" also occurs in science (Ramsey 1957, 47–48).

So, it appears that proper speech about the complex realities dealt with in either QM or theology must "[hold] the *via positiva* [which necessarily involves Ramsey's logical improprieties] in creative tension with the *via negativa*." (Paul 2006): "Immortal, invisible … in light … hid from our eyes;" "an electron is neither a particle nor a wave … and it is both!" Faced with complexities, quantum or divine, a positivistic language that claims to eschew paradox and not balanced by a negative language of denial will, at best, breed confusion, and, at worst, wreak conceptual havoc, not only in the respective domains of science and theology, but in discussions of their relationship (Poon 2022).

Turning to visualizability, recall that for Bohr, there are suitable words "to describe" classical physics because it is associated with "physical pictures." This recalls a famous argument between Heisenberg and Schrödinger (Miller 1986; de Regt 1997). The latter was motivated to invent his 1926 wave mechanical formulation of QM partly because of his dissatisfaction with the lack of *Anschaulichkeit*, or "visualizability," in the 1925 matrix mechanics of Heisenberg, Born and Jordan. Heisenberg's dissenting response is his 1927 article announcing the Uncertainty Relation entitled "On the *anschaulichen* ('visualisable') content of quantum theory."[13]

Interestingly, quantum pedagogues since this debate have mostly opted for Schrödinger's wave mechanics in introducing quantum arcana to beginners, precisely because of its intuitive "visualisability."[14] Indeed, Bern Thaler (2000) from the University of Graz (where Schrödinger once taught) published a text describing computer animations in QM for undergraduate teaching. Thaler (2000, v) tells us that after showing a movie to his students, he will "explain step-by-step what can be learned from the animation," and that each movie should "provide some motivation for the effort to understand the theory behind it." In other words, the visualizations are not of quantum reality *per se*, because "behind" these lies "the theory," so that a *hermeneutic* is needed in order for the student to "learn from" the visualizations.

This discussion about quantum *Anschaulichkeit* bears comparison with the iconoclastic controversy in eighth/ninth-century Byzantium[15] in which theologians debated the propriety or otherwise of pictorial representations of divine realities (Louth 2007). Byzantium eventually affirmed the value of icons, albeit carefully hedged with a nuanced hermeneutic (Evdokimov 1989). Visual representations are dangerous in both domains because they may be confused with reality—visualization becomes idolatry. Nevertheless, the affirmation of visualizability in either case is an important antidote against tendencies to cut loose from materiality—to treat QM as a purely mathematical construct when it is in fact one of the most successful physical theories for describing physical phenomena, or to over-spiritualize Christianity, which Archbishop William Temple (1949, 478) once described as "the most avowedly materialist of all the great religions" because of the incarnation (John 1:14).[16] For further development of these thoughts and to set them in wider cultural and theological contexts, see Fuller and Jasper (2014).

Conclusion: A Participatory Theology of Science

We have seen that a good deal of linguistic sleight of hand since Eddington onward has been deployed to fast track from QM to some form of idealism, where the mind of some sentient "observer" is inextricably "entangled" with the nonsentient world being "observed." The motivation presumably comes from a longstanding unease felt by many that classical, pre-QM science inhabits a universe in which there is no room for sentient beings, including the scientists who produced such a world picture in the first place. So, if the "fast track to quantum idealism" offered by Eddington, Ward and company is untenable, are we left with a universe with no room for sentient beings? Not necessarily. One could choose the "slow track" of careful, unglamorous argumentation to show why QM really does require the participation of sentient minds. Irrespective of whether such work will succeed—we ourselves are not yet convinced by any attempt to date—we want to close by sketching a "middle way."

Recall first that there *is* a sense in which QM does highlight the role of sentient beings. The scientist's choice of experiments dictates whether the outcome should be modelled as a particle or a wave (but never both). We have also seen how the assignment of entropy in CSM depends on how coarse- or fine-grained our models are. What therefore QM and CSM *both* point to is not idealism ("mind over matter") but *participation*. To unpack what we mean, we turn to the tradition of *imago Dei*.

What the *imago Dei* might mean has been long debated by Christian theologians. The attribution of rationality and morality are leading traditions. But a less-dominant strand takes the first Biblical divine act seriously (as, indeed, the last)—to *create* a world. If the primary act of God is to create a world, it is coherent to suggest that to "image God" means to create an image of the world. Humans as participative "created co-creators" is the main theme of, for example, the theologian Phillip Heffner (1993), but a more faithful *imago Dei* reading of sub-creation, or "imaged-creation" has the cocreators acting in the image of the Creator when they themselves create an image of the universe, rather than any aspect of or object within the universe itself. Arguably, "creating an image of the universe" through engagement with the first created universe is a strikingly faithful description of science as a human activity, and chimes well with our descriptions of both QM and CSM. Once QM and CSM are perceived not as direct visions of the universe itself, but as humanly created images of that universe, it becomes less surprising that sentient observers play active, rather than purely passive, roles.

The essential three-way relationality between Creator, human, and the material world that arises in all human observation and perception (including the pre-scientific), has been given aesthetic perspective by David Bentley Hart, who speaks of the "metaphysics of participation." The sheer mystery of how human minds are able to participate in the rationality of creation, through the construction of images of that created order, both prior to and post perception, becomes a participation in the analogy of being, that itself explicates the notion of humans created *in imago Dei*. As Hart (2003, 311) puts it, "Between the desert of absolute apophaticism and immobile hypotaxis of absolute cataphaticism stands the infinity, the unmasterable parataxis, of analogy, at home in an endless state of provisionality and promise." Hart explicates how we have no direct, imminent grasp of reality, nor is the world entirely hidden from us, but we participate in a "middle way" of access to the material world by analogy, perhaps pointing to a future that holds a closer and more intimate relationship. Just as in the case of iconography, it is important to know just how elevated, and at the same time how humble and inexact, our (scientific) images of the world are; both how powerful and so aporetic the notion of analogy in science as much as in theology.

But theological discussion of "participation" tends to stop there, without unfolding what participation at this level might mean. Our definition of "observer," as one who creates, in image, a corresponding, quantitative and dynamic model of the world, unpacks what a creation theology of participation actually means in the light of modern science. It identifies the locus of Hart's "analogies" as the scientific models themselves. These created objects, whether in CSM or QM, sit before the observers in their mathematical, computational or visual form imaging their own creation in *imago Dei*, but at the same time *apophatically* related to the real world. The latter is accessed immanently *via* the models/images alone.

This account of a participative theology of science differs radically from "natural theology." For in a relation of participative creation *in imago Dei*, the human gaze onto the world shares, by analogy and in image, at least the same "direction" as that of the divine. We gaze from the divine perspective, if not with the divine perspicuity. In this sense, an observer-dependent approach is perfectly opposed to any anticipation of perceiving the divine nature *through* the lens of the world, as in traditional natural theology. Rather, in this participatory picture *in imago Dei*, the divine gaze enters the world through the gaze and scientific labor of the human. Such a participatory theology of science, which resonates with QM and CSM alike, is both apophatic, in that God is hidden "behind" the human gaze onto the world, and cataphatic in its shared infinitude of possibility and promise, as well as the surprising divine immanence that this "geometry of participation" implies (McLeish 2014).

Finally, then, to return to the titular question, we find it hard to see what QM can offer to theology that is truly distinctive. In particular, claims that QM offers a unique way to reintegrate sentient observers into the scientific world picture are often based on not much more than repeated "register switching." Moreover, we have reviewed how "QM-speak" can be formally transformed into the language of CSM, further undermining claims to distinctiveness. On the other hand, *participation* of sentient beings making choices, for example, whether to detect an electron as a wave or a particle, is built into the structure of QM. We have argued that CSM, born in the same era as QM, makes the same case even more powerfully in the way entropy is defined. Both QM and CSM point to a participatory theology of science, which provides a distinctive contribution to wider discussions of humanity as *imago Dei*. The way QM contributes to theologizing, therefore, will be as a part of science as a human endeavor, but as one of those parts that, like CSM, very insistently points to participation.

Notes

1. Modern cosmology, with roots in general relativity but now joined with QM, perhaps competes with QM for attention.
2. A cursory online search uncovered some 10 items, for example, Boni (2016), Faries (2017), Goswami and Onisor (2019).
3. The "transcript" from the lecture website is *not* verbatim, but a formal write-up of similar material. We quote from the recorded version, which one of the authors transcribed.
4. We use underlining to highlight key linguistic moves.
5. "Eight slithy toves gyre and gimble in the oxygen wabe" describes the configuration of electrons in the oxygen atom.
6. Beaney and Chapman's (2021) summary of Stebbing ([1937] 1944).
7. More precisely, the "squared modulus" of the propagator, which is in general a complex number.
8. Beware of register switching. "Real" and "imaginary" here have their strict mathematical senses of "real numbers" (everyday numbers) and "imaginary numbers" (multiples of $i = \sqrt{-1}$).
9. Wigner, like Eddington, was a quantum idealist (we owe this observation to Prof. Mark Harris). On the role of observers, we believe that Wigner is a better guide for CSM than for QM.
10. Loosely, the square of the wave function, technically the mathematical object $\langle \Psi \mid \Psi \rangle$.
11. In two popular science books by the noted physicist George Gamov ([1965] 1993), the title character Mr Tompkins enters dream worlds in which quantum mechanical or relativistic effects become everyday because of alterations in the fundamental constants of physics.
12. Gamov gave the initials C. G. H. to his Mr Tompkins, these being the standard symbols for the speed of light, the gravitational constant, and Planck's constant.
13. For the Kantian overtones of this debate, see Holton (2016).
14. *Anschauliche* is often rendered as "intuitive" in discussions about QM, for example, by Miller (1986).
15. Compare Holton (2016), who says in his 1927 article, "Heisenberg was … being an iconoclast, forbidding the realistic pictorial impetus, … as … had been done … in Byzantium."
16. Temple (*idem*) suggests that John chose the Greek word *sarkx* (flesh) "because of its specifically materialistic associations."

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