Quantum Realism Part I. The Observed Reality

Chapter 3. The Light of Existence

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"There is a theory which states that if anyone discovers exactly what the Universe is for and why it is here, it will instantly disappear and be replaced by something even more bizarre and inexplicable. There is another theory which states that this has already happened." (Adams, 1995)

If the universe booted-up from one photon, in the beginning there was light but not as we know it. The last chapter proposed that a white-hot point of light ripped our universe from the quantum womb in a massive million, billion, billion, billionth of a second chain reaction, until expanding space cooled things down enough to stop it. The tiny inflated region then expanded at light speed and its quantum fluctuations were the seeds from which galaxies and stars formed. In this view, light was the first "thing" to exist so it is natural that we have often wondered *what is light?*

3.1. WHAT IS LIGHT?

Even in pre-scientific times, light was considered primal. In Egypt, light from the Sun god Aten sustained all, and in the bible, God created light before the sun, moon, stars or man. Light is still all around us today but it remains a mystery. As Einstein said just before he died:

> "*All these fifty years of conscious brooding have brought me no nearer to the answer to the question 'What are light quanta?' Nowadays every Tom, Dick and Harry thinks he knows it, but he is mistaken*." (Walker, 2000) p89

This statement remains true today because science still can't answer the question "*What is light?*"

3.1.1. The mystery of light

Science reduces the question *What is light?* to what it does but the mystery remains that what it does isn't physically possible. Even after centuries of study, physics still can't say why:

1. *Light doesn't fade.* Every physical wave diminishes in amplitude over time but light doesn't, even after it has traveled for billions of years.
2. *Light has a constant speed.* The speed of a wave depends on the medium it travels through but light goes at a constant speed in space that is physically nothing.
3. *Light is a wave and a particle.* It is physically impossible for a wave to act like a particle or for a particle to act like a wave but light is a *wavicle* that denies this.
4. *Light always finds the fastest path.* It isn't possible for a physical particle to find the fastest path to every possible destination but light does.
5. *Light chooses its path after it arrives.* A physical particle can't pick the path it takes to a given destination after it arrives but light does just that.
6. *Light can reveal an object it doesn't physically touch.* In a purely physical world, it shouldn't be possible to detect an object without touching it but light does exactly that.

7. *Light vibrates outside space.* Light vibrates into a dimension that doesn't physically exist.

Most physicists think light is physical yet physical reality can't explain what it does. The paradox that physical light acts in non-physical ways is exemplified by *wave-particle duality*, that light is like a wave sometimes and sometimes like a particle. A wave traveling in a medium doesn't arrive like a particle at a point, but light does. A particle going in one direction can't go in many directions at once like a wave, but light does. No physical wave ever becomes a particle and no physical particle becomes a wave, but light seems to exist as a mixture of both.

3.1.2. Is light a particle or wave?

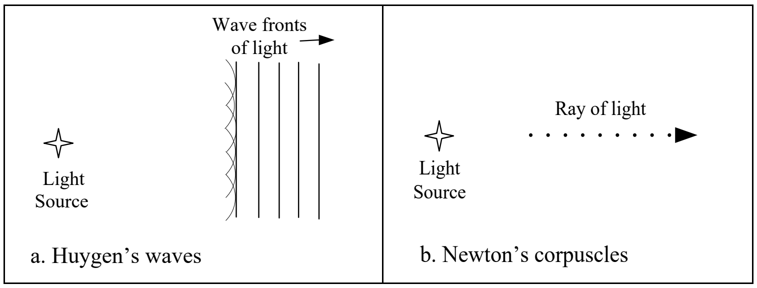


Figure 3.1. a. Huygen's wave front. b. Newton's corpuscles

The question of whether light is a wave or particles has a long history. In the seventeenth century *Huygens* noted that light beams at right angles pass right through each other like waves while arrow-like particles should collide. He concluded that light was an *expanding wave front* that spreads in all directions, with each strike point the center of a new little wavelet. If the wavelets interfere as they spread, the trough of one wave will cancel the crest of another to give a forward moving envelope that at a distance from the source acts like a ray of light (Figure 3.1a). *Huygen's principle* that *each wave front point is a new wavelet source spreading in all directions* explained reflection, refraction and diffraction.

In contrast, Newton noted that light travels in straight lines rather than bending round corners as sound waves do when we hear someone talking in the next room, so concluded that light was particle-like *corpuscles* that traveled in straight lines to match the optics of the day. His particle model explained only reflection and refraction (Figure 3.1b) but for some reason carried the day.

Two hundred years later, Maxwell, building on Faraday's idea of a field, wrote the equations of light as an electromagnetic wave based on a mechanical model of rotating vortexes. The equations worked so they were quickly accepted, and this seemed to settle the matter that light was a wave.

Maxwell's original equations assumed that light waves travel through a "luminiferous aether" but the Michelson-Morley experiment then dispelled the idea that light traveled in a physical medium. Then Einstein equally convincingly argued from the photo-electric effect that light comes in particle-like packets called photons. The result was two theories, both of which worked to a degree.

Over centuries, the theory of light has swung from Huygens' waves to Newton's corpuscles to Maxwell's waves to Einstein's photon packets with no clear winner, so modern physics finally gave up. It concludes that light is wave *and* a particle, though no-one can explain how such a *wavicle* is possible. Three centuries after Huygens and Newton, we still don't know whether light is a wave or a particle and the miracle of wave-particle duality essentially enshrines our ignorance. Physical realism could have explained light as a particle or as a wave but it can't explain how it can be both.

3.1.3. Young's experiment

Wave-particle dualism is embodied in a simple experiment carried out by Young over two hundred years ago that still baffles physics today – he shone light through two slits to get an interference pattern on a screen (Figure 3.2). Only waves diffract like this so light must be a wave but if so, why do light rays follow lines? Conversely, if photons are particles, how can they interfere like waves?

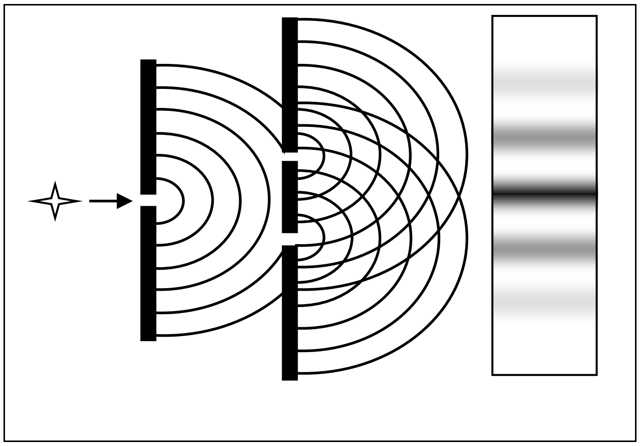
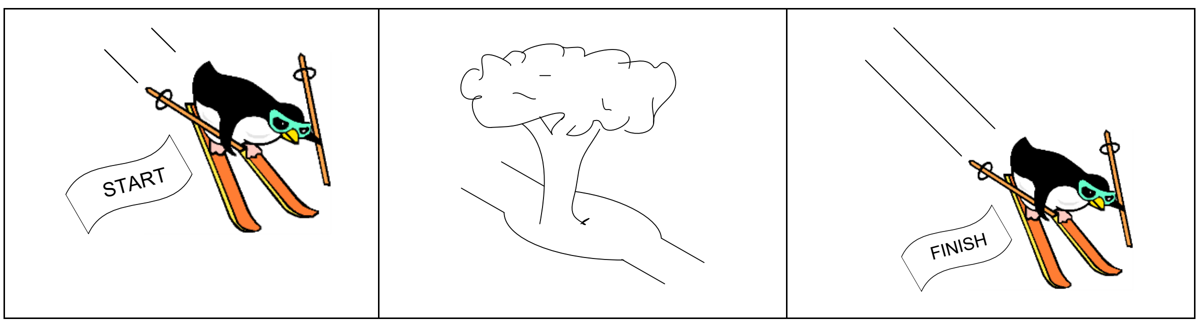


Figure 3.2. Young's double slit experiment

To find the answer, physicists sent *one photon at a time* through Young's slits. Each photon gave the expected dot on the screen as a particle would but over time the dots formed an interference pattern whose most likely impact was *behind* the barrier between the slits! The effect was independent of time, so one photon shot through the slits each day still gave an interference pattern. Since each photon can't know where the previous one hit, how does "interference" occur?

In an objective world, one could just see which slit a photon went through before it hit but our world doesn't work like this. Detectors placed in the slits to see where the photon goes just fire half the time as expected. A photon *always* goes by one slit or another, *never* through both, so interference shouldn't be possible. When we look, we see a photon particle but when we don't, it behaves like a wave. It is as if a single skier set off, went around *both* sides of a tree on the way, then crossed the finish line as one skier (Figure 3.3). The problem is:



***a.** A particle starts* ***b.** A wave flows* ***c.** A particle finishes*

Figure 3.3. Wave-particle duality

1. *If a photon is a wave*, why doesn't the photon smear over the detector screen as a wave would?
2. *If a photon is a particle,* how can one photon at a time give an interference pattern?

The problem applies to every quantum entity as electrons, atoms and even molecules show Young's two-slit diffraction (M. Arndt, O. Nairz, J. Voss-Andreae, C. Keller, & Zeilinger, 1999).

3.1.4. The Copenhagen compromise

After centuries of dispute over whether light is a wave or particles, Bohr devised the *wave-particle* compromise that holds today suggesting in the 1920's that the two views are "complementary", i.e. both true, and nothing better has been found since:

"*…nobody has found anything else which is consistent yet, so when you refer to the Copenhagen interpretation of the mechanics what you really mean is quantum mechanics.*" (Davies & Brown, 1999) p71.

The resulting *don't ask, don't tell* policy lets a photon be a wave when we don't look as long as it is a particle when we do, so physics can apply particle or wave equations as convenient. In no physical pond do rippling waves turn into particles nor do billiard-ball particles ever become waves, but Bohr successfully sold the big lie[1] that *light is a wavicle.* As Gell-Mann said in his 1976 Nobel Prize speech:

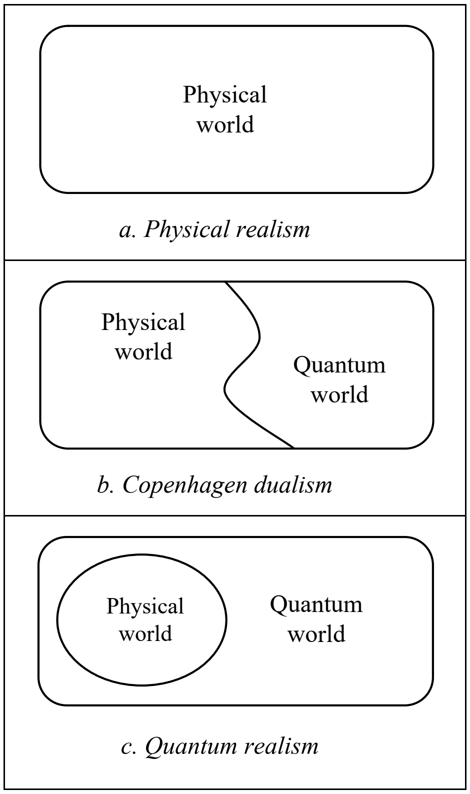


Figure 3.4. a. Physical realism, b. Bohr's dualism, c. Quantum realism

"*Niels Bohr brainwashed a whole generation of physicists into believing that the problem (of the interpretation of quantum mechanics) had been solved fifty years ago*."

Bohr's wave-particle dualism is a mystical marriage of convenience between incompatible domains, accepted by those who want to believe, just like Descartes' mind-body dualism.

Physical realism, that the physical world is all there is, has no room for a quantum world that doesn't follow physical laws (Figure 3.4a). Bohr's Copenhagen dualism, that the quantum world could be said to exist alongside the physical world solely for the convenience of physics was an admission of failure not a theory advance (Figure 3.4b) (Audretsch, 2004) p14). It was the beginning of *fake physics*, for even as he publicly accepted that quantum theory implies a quantum world that in some way exists, he denied the quantum world existed at all in private. One can't have the best of both worlds if they are incompatible.

Quantum realism rejects both physical realism and Bohr's Copenhagen compromise. It proposes instead that physical events are a subset of quantum events (Figure 3.4c) so classical mechanics is a subset of quantum mechanics. We now explore this possibility.

3.1.5. How come the quantum?

As Feynman famously said:

"*… all the mystery of quantum mechanics is contained in the double-slit experiment*." (Satinover, 2001) p127.

Quantum theory explains Young's results as follows:

A photon wave function spreads in space by the equations of quantum theory. This ghostly wave goes through both slits to interfere with itself as it exits but if observed immediately "collapses" to be a particle in one place, as if it had always been so. If we put detectors in the slits, it collapses to one or the other with equal probability. If we put a screen behind the slits, it interferes with itself, then collapses on the screen due to the prior interference.

The mathematics doesn't say what this wave is that goes through both slits, nor why it shrinks to a point particle when observed, hence Wheeler's question: *How come the quantum*?

[1] A big lie is a statement so outrageous that people think it must be right or it wouldn't be said.

To see how strange this is, suppose the initial photon in a two-slit experiment hits a screen at some point to become the first dot of what will *always* turn into an interference pattern. Now suppose that in another experiment with a detector blocking the other slit, the initial photon goes through *the same slit* to hit the screen at the *same point* to become the first dot of what will *never* be an interference pattern. The difference between these outcomes *must* exist from the start but *the physical events are identical* – a photon goes through the same slit to hit the same screen point. The only difference is whether *the slit the photon didn't go through* was blocked or not.

How can blocking the path that the photon didn't take be part of the later result of an interference pattern or not? How can the slit a photon *could have gone through but didn't* decide if there is interference or not? How can a *counterfactual*, an event that didn't physically happen, change a physical outcome?

In a purely physical world, such a thing is impossible. Quantum theory's unlikely tale of imaginary waves that collapse when viewed makes no physical sense, yet it is the most fertile theory in the history of science. This leaves two key issues unresolved:

1. *What are quantum waves?* What exactly is it that spreads through space as a wave? The current answer, that the waves that predict physical events don't exist, is unsatisfactory.
2. *What is quantum collapse?* Why do quantum waves restart at a point when viewed? The current answer, that quantum waves collapse "because they do", is equally unsatisfactory.

Until it answers these questions, quantum mechanics is just *a recipe without a rationale*.

3.2. THE QUANTUM WAVE

Maxwell's equations describe light waves that vibrate in the imaginary plane of complex numbers, so the nothing of empty space vibrates in a direction that is nowhere in physical space. Current theory is that the primal existence we call light is a wave of nothing vibrating nowhere. In contrast, if space is a surface, light can be a wave on that surface, and if that surface is made by quantum processing, it can be a processing wave. This section explores the idea that light is a processing wave passed on by a quantum network that is the "… *primary world-stuff*" (Wilczek, 2008, p74), whose nodes some call the "*atoms of space*" (Bojowald, 2008).

3.2.1. Light is a wave

Maxwell's equations describe a photon as a wave in an electromagnetic field that sets *imaginary* values outside our space. If this wave vibrates slowly, we get radio waves, faster vibrations are visible light and very fast vibrations are x-rays or gamma rays (Figure 3.5). Visible light is the part of the spectrum that vibrates about a million-billion times a second, gamma rays are a billion times faster while radio waves vibrate just a few times a second. For simplicity, from now on the term "light" refers to *any electromagnetic wave frequency*.

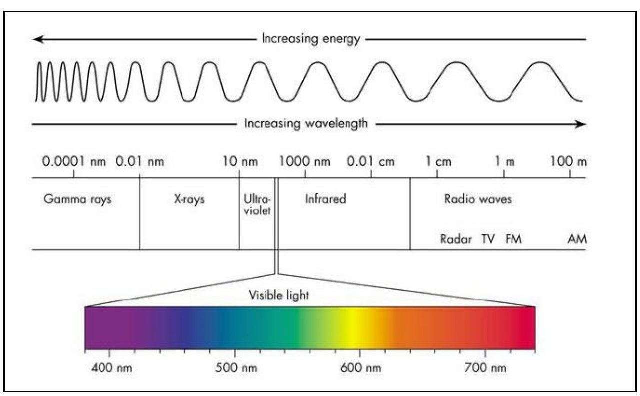


Figure 3.5. The electromagnetic spectrum

In Newton's optics, a *light ray* moves on an axis that can contain many photons *polarized* in different ways. Modern filters can polarize a ray one way and lasers can even produce a *pulse* of light of one frequency in one polarization plane on one axis, which is one *photon.*

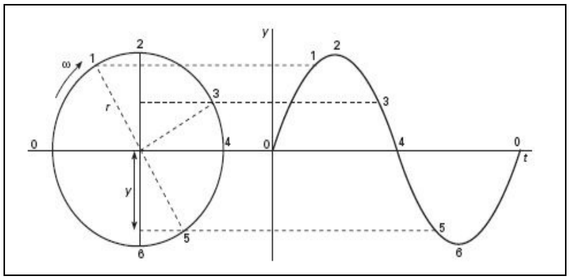


Figure 3.6. A circle maps to a sine wave

When such techniques produce rays of polarized light that are *out-of-phase,* the crests of one match the troughs of the other. The result is two rays that are separately visible but combine to give darkness, as the out-of-phase photons cancel each other just as out-of-phase waves do. *This light + light = darkness confirms that light really is a wave* as particles can't do this. Note that flashlight beams can't do this because they aren't polarized.

We also know the type of wave. Light is a *sine wave* that in mathematics maps to an extended circle (Figure 3.6), so a pointer turning in a circle like a clock hand can describe a sine wave, as shown in Figure 3.7.

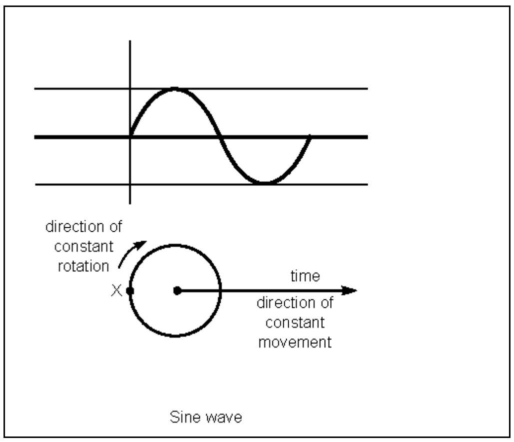


Figure 3.7. A sine wave is a moving rotation

Wave theory describes a water wave as a sine wave caused by the forces of gravity and elasticity acting at right angles to the water surface. When the wave arrives, a surface water molecule is pushed say up until gravity pulls it back down, then the water elasticity pushes it back up, etc. The wave just moves water molecules up and down so corks just bob up and down as a wave passes. What travels on the surface is a *transverse vibration* not the water itself.

We describe light in the same way but call it an *imaginary wave* because no-one can say what is going up and down. *Naming* a cause doesn't *explain* it, so the term electromagnetic field is just a placeholder for what we don't understand. Yet if light is a wave, it must vibrate on space, and this is something we find difficult to imagine.

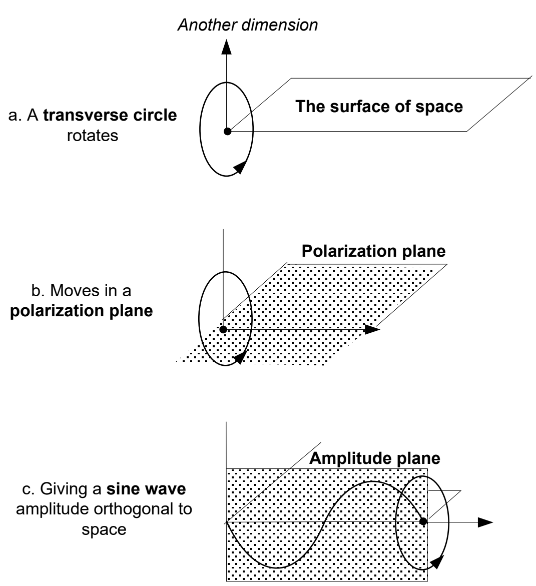


Figure 3.8. A transverse circle moving on space is a sine wave

3.2.2. We are flatlanders

Does light vibrate in a physical direction? In physical realism, it must do so because space gives all possible directions. Sound is a *longitudinal wave* that vibrates air molecules in its travel direction, so there is no sound in empty space because there are no air molecules there. In contrast, light travels in the vacuum of space or we couldn't see the stars at night.

It is a *transverse wave,* that vibrates at right angles to its line of travel but that *can't* be a physical direction because space is *isotropic* so "up" from one view is "down" from another. Simply put, physical space has no "free" direction for positive-negative electromagnetic values to vibrate into so *physical realism can't explain how light vibrates at all.*

Space as a *surface* however lets light move *on* space as waves move *on* a lake except this surface has three dimensions not two. Light then is a transverse quantum wave vibrating into a plane beyond our space, just as complex number theory describes, which this makes us 3D "Flatlanders".

In Abbot's story, the *Flatlanders* were beings who lived their lives on a 2D surface (Abbott, 1884). Everything they did happened in two dimensions not three, so they could see a circle say but could only *imagine* a sphere as expanding and contracting circles passing through their reality.

Now imagine a point moving on their flat land that sets values in a *transverse circle* at right angles to their space (Figure 3.8a). Flatlanders could only conceive of these values existing in a *complex plane* that didn't exist for them, as we do for light. As the point moves, it defines a *polarization plane* in their space (Figure 3.8b), again as we have for light. To explain this, they might postulate an "unreal", to them, *sine wave* amplitude (Figure 3.8c), just as we do for electromagnetism.

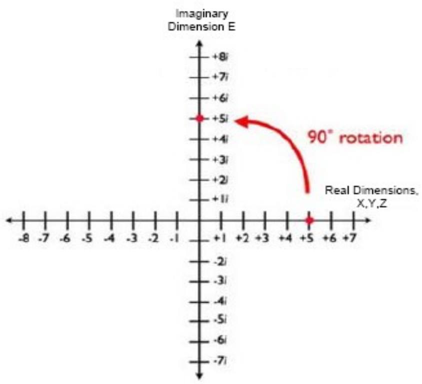


Figure 3.9. Complex rotations

That light is a transverse rotation *outside* space suggests that complex numbers explain electromagnetism because light *really is* rotating outside space, so:

"*In quantum mechanics there* ***really are*** *complex numbers, and the wave function* ***really is*** *a complex-valued function of space-time.*" (Lederman & Hill, 2004) p346

Complex numbers describe a rotation into a dimension outside our space[2] (Figure 3.9) that we call *imaginary* because it doesn't exist in our space, just as Flatlanders might call a third dimension that doesn't exist in their space imaginary. But that a dimension doesn't exist in our space doesn't mean it doesn't exist at all if, like Abbot's Flatland, our 3D space is *contained* within a higher dimensional space.

If our three-dimensional space exists within a quantum network with four degrees of freedom, light can vibrate into a dimension outside space. In simple terms, *physical space is a surface within a four-dimensional quantum space*. If our bodies exist as quantum waves that vibrate into a quantum space, we can't enter that space any more than a water wave can leave the pond surface it vibrates on. It follows that we are *three dimensional Flatlanders.*

3.2.3. The medium of light

All waves vibrate a medium so a light wave needs a medium. *Something must move to make light waves* but with no physical ether, current physics simply declares that:

"*… we accept as nonexistent the medium that moves when waves of quantum mechanics propagate*." (Laughlin, 2005) p56.

In current electromagnetic field theory, electric changes cause magnetic changes that cause electric changes and so on, in a circular fashion. So light is said to be a:

"*… self-renewing field disturbance*." (Wilczek, 2008) p212.

[2] Complex number theory describes a *rotation* into an imaginary plane. In normal multiplication, multiplying a number by two doubles it, e.g. 5 x 2 = 10. Multiplying by 4 adds it four times, e.g. 5 x 4 = 20. In complex multiplication, *i* is a 90° *rotation* into an "imaginary" plane, so times *2i* is a 180° rotation that turns a number into its negative, e.g. 5 x *2i* = -5. Times *4i* is a 360° rotation that has no effect, so 5 x 4*i* = 5.

This circularity begs the question of what renews the fields that renew? That an electric field powers a magnetic field that powers the electric field is like Peter paying Paul's bill and Paul paying Peter's bill. With such logic, I could borrow a million dollars today and never pay it back. According to current physics, light is a cosmic Ponzi scheme!

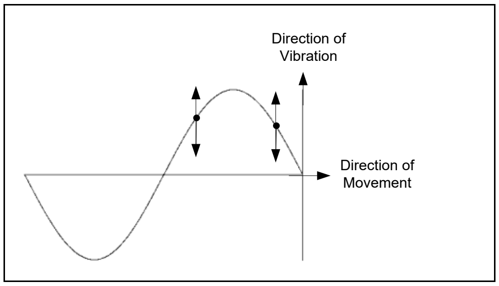


Figure 3.10. Physical waves vibrate matter up and down ***on*** *a surface*

Physical waves that move matter up and down as shown in Figure 3.10, inevitably involve friction so by the second law of thermodynamics they eventually fade, with no exceptions[3]. Yet ancient light that has traveled the universe for billions of years to reach us still arrives at the same speed. Light as a *frictionless wave of nothing* is physically impossible so it can't be based on any physical movement. A century of physics still hasn't answered the question:

How can vibrating nothing (space) create something (light)?

Quantum realism answers that space is no more empty than an "idle" computer is idle[4], so the:

"*… vacuum state is actually full of energy…*" (Davies & Brown, 1999) p140.

Space is active because the quantum network never stops so it is always "on" to power light. Electricity and magnetism correlate not because they mutually cause each other but because quantum events create both. Physical realism can't say what powers light but in quantum realism*, the quantum network maintains light as a wave.*

Feynman called quantum theory's quantum field a *vector potential.* Born called it a *probability amplitude,* Hiley called the *quantum potential* (Davies & Brown, 1999) p138, and others today call it the *quantum function (Ψ),* but none can explain how a mythical field predicts physical reality. Quantum realism calls it the *quantum field* and contends that it predicts physical events because it generates them.

3.2.4. The speed of space

Einstein deduced from how our world behaves that the speed of light is a maximum but he didn't explain why light has that speed and no other and saying that light goes at light speed because it has no mass doesn't explain why there is a maximum speed at all. Why not the speed of light plus one? What sets the speed limit of our universe? The current view, after almost a century of consideration, is that:

> "*… the speed of light is a constant because it just is, and because light is not made of anything simpler*." (Laughlin, 2005) p15

Yet "*because it just is*" has never been a very satisfactory answer in science. The speed of a wave depends on the medium it travels through not the wave itself, so the speed of light should be defined by the space that physical realism calls nothing. If light is a wave of processing passed on a network, it must move at a finite rate if the quantum network cycles at a finite rate as our computers do. Yet while a 5GHz computer runs 5,000,000,000 cycles per second, the quantum network cycles at an astonishing 10^{45} times a second! If light is processing passed from one node to the next each cycle, its speed follows from the cycle rate and the node-to-node distance[5] of the network, so *what we call the speed of light is really the speed of space*.

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[3] Planets orbit forever but the gravity that maintains this derives from the same quantum source as light.

[4] Processing must continually run, so an "idle" computer still runs a null cycle, i.e. it doesn't do nothing.

[5] The speed of light $c=L_P/T_P$, where L_P is a Planck length of 1.616×10^{-35}meters and T_P is Planck time of 5.39×10^{-44} of a second. This gives the speed of light as 299,792,458 meters per second (see here).

Yet the speed of light isn't constant, as light slows down in water. When light moves in water, we *say* the medium is water, and if it moves in glass, we *say* the medium is glass but if it moves in space, we call it a wave of nothing! In quantum realism, whether light travels through glass, water or space, its medium is always the quantum network. Light slows down in water not because its medium is water but because the quantum network slows down when it has to process matter and the speed of light is defined by the speed of the quantum network. Light slows down in water for the same reason that a computer game slows down under load and it slows down due to gravity for the same reason. The quantum network runs at different rates depending on load but photons still keep in a strict sequence, one behind the other, like the baggage cars of a train driven by the same engine. Each node passes on the photon it has then accepts another in the line. If the engine slows down under load near a massive star, photons go slower *but still keep the same order* so in gravity lensing, photons from a cosmic event arrive on earth at different times by different paths but still arrive in lock-step order. This maintains causality, as if one photon could overtake another one might see an object arrive before it left! *Causality requires photons to stay in sequence and the quantum engine rigorously maintains this*.

3.3. THE QUANTUM PROCESS

If light is a quantum wave and quantum waves are processing waves, what process is passed on? This section explores the idea that one quantum process generates the entire electromagnetic spectrum, from radio-waves to gamma rays.

3.3.1. The fundamental process

A particle model has fundamental particles but a processing model needs a fundamental process. In our computing, every processor has a *command set,* so an arithmetic processor might have "add one", "subtract one" and "add zero" as core commands. Most computers have more commands but the basic idea is the same. As computing expanded to databases and networks, new commands were added, giving *complex instruction set computing* (CISC), until it was discovered that *reduced instruction set computing* (RISC) is more efficient.

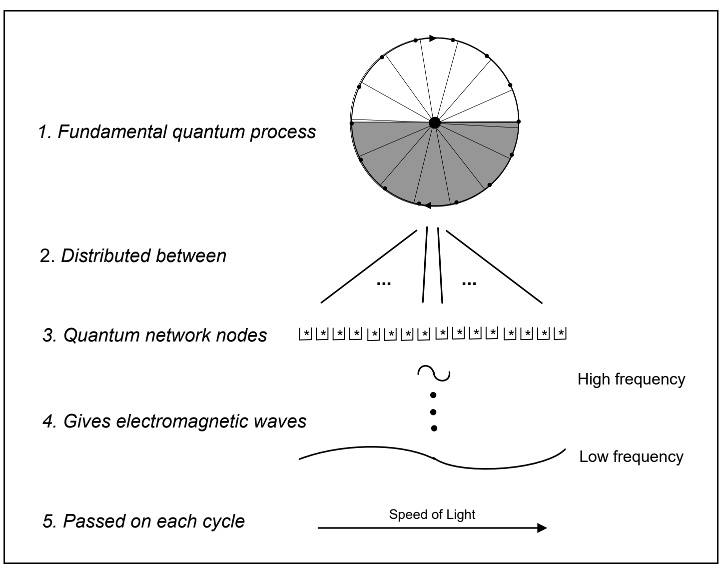

Figure 3.11. Light is one quantum process distributed more or less

The proposed command set for the quantum network is the ultimate RISC design of *one command*:

Set the next value in a transverse circle

A transverse circle *on* space permits positive-negative electromagnetic values and it always works because a circle ends where it begins. A full transverse circle completed by one node in one cycle is a null process, as equal positive-negative displacements cancel to the "nothing" of space. The displacements aren't physical but just values set in quantum space, as complex number theory says. *Light is then this fundamental quantum process spreading on the quantum network.*

Figure 3.11 shows how one circular process distributed more or less can give the entire electromagnetic spectrum. The *fundamental quantum process* (1) is *distributed* between (2) *quantum network nodes* (3) that run it at some *frequency* (4) as a wave passed on at the *speed of light* (5). As as a circle rotation can map to any sine wave, one circular process distributed more or less can map to any frequency in the electromagnetic spectrum. The frequency of a photon depends on how it is distributed because *processing distributed runs slower not less*. A longer wavelength divides the same process more, so each node runs more slowly.

Imagine two people sharing a shovel where in the time one person can dig one hole, two people sharing a shovel can only dig half a hole each, and if the shovel is shared among more people, each digs even more slowly. In this analogy, the "shovel" photons share is a server providing one basic quantum process per quantum cycle.

To review, one quantum process sets a transverse circle of values at right angles to space. If that process runs in one node, the displacements cancel to give space. If it runs in more than one node, the result is light whose frequency depends on how many nodes share the process, Sharing the process over more nodes gives light with a longer wavelength and a slower frequency. The process spreads each cycle by the pass-it-on protocol, leaving the nodes behind to run it to completion. As new nodes begin, others complete the process, so the total server processing demand per photon stays the same. Since the basic quantum process is also the null processing of space, *light is in effect space spread out*. A photon has no rest mass because if it rested for its wave train to catch up, it would become space. *Every photon in the electromagnetic spectrum is the same quantum process distributed more or less*.

3.3.2. The energy of light

Energy is the *capacity to do work*, defined as a force times the distance it acts, so work is the result of energy and *energy is stored work,* e.g. as an object falls under the force of gravity, it acquires *kinetic* energy as it falls and that energy is released when it hits the ground. Light has energy and according to Einstein, mass is also a form of energy. The idea that energy transforms into different forms but is conserved overall has been very successful.

What then is energy in processing terms? The energy of light depends on its frequency, so higher light frequencies like x-rays have more energy. If short wavelength light is the same quantum process distributed over fewer nodes, each gets a bigger processing share and so completes the process faster. A long wavelength photon in contrast spreads the same process over more nodes, so each takes longer to complete. If higher light frequencies have more energy because each node gets more processing, *energy is the quantum processing rate at the node.*

Over a century ago, the energy of light was found to vary *linearly* with frequency. This wasn't expected, as light was seen as a wave and the energy rate of a water wave varies as the *square* of its frequency. If light was a physical wave, a furnace emitting light at many frequencies should increase at all frequencies as it got hotter, so a very hot furnace should in theory give a lethal dose of x-rays, but in practice it didn't. That light emitted from furnaces didn't obey the laws of physical waves was called at the time the *ultra-violet catastrophe.*

Planck solved the problem by making atoms emit energy in multiples of a basic quantum amount later called Planck's constant. Assuming the light emitted was not continuous gave Planck's relation:

Light Energy = Plank's constant x *Frequency*

That light energy varied directly with frequency not its square predicted the observed radiation correctly. Einstein then generalized this to apply to all light, based on the photo-electric effect, but why light waves arrive in the "lumps" we call photons was a mystery that remains to this day.

If a photon represents the fundamental process of the quantum network, it is basic in the sense that no activity can be less than it. Quantum processing can't be less than a transverse circle because this is the fundamental network operation. How much this process is *shared* among the nodes of the photon wavelength defines how long each node takes to complete it, which is the light frequency. If the wavelength is longer, each node gets a smaller share and so takes longer to complete the process, so *energy as the node processing rate* varies inversely with wavelength and directly with frequency, as Planck deduced from the data. More exactly, if Planck's constant is the transfer of one quantum process per second, energy as the node processing rate will be Planck's constant times its frequency, which is

Planck's relation[6]. Quantum realism thus *derives* Planck's relation from first principles. We can call the fundamental operation of the quantum network a *Planck process*.

A water wave's energy seems to vary continuously but *light waves can't do this.* A photon is one Planck process shared on a quantum network where every wavelength is a discrete number of nodes, so its wavelength can increase or decrease by one node but can't vary continuously. It must change one node at a time so each energy change is discrete. *A photon's energy is quantized because its wavelength is digital.*

One less node running the same process changes the node processing rate, or energy, by a fixed amount as each node removed shortens the wavelength by one, leaving those remaining to run the same processing. As the wavelength reduces, higher energies are harder to come by because removing one node from fewer nodes changes the energy more, so the ultraviolet catastrophe didn't happen. This predicts that the highest frequency of light, here called *extreme light*, is a wavelength of two Planck lengths, and that it must double its energy to reach the next frequency, which is empty space!

3.3.3. Planck's constant

Planck's constant is the basic unit of energy in physics so it's the *smallest possible energy transfer*. If a Planck process is the fundamental quantum network operation, then Planck's constant represents that process. The electromagnetic spectrum has many types of light, but if every photon is the same process spread out more or less, the simplest existence is based on the fundamental network process. Planck's constant is a tiny energy transfer in our terms but at the quantum scale, one Planck process is the maximum node bandwidth. Since the total processing of any photon is just that, the smallest energy transfer is one photon. In our terms, the energy of a photon is a *multiple of* Planck's constant but in quantum terms, the Planck process is *divided* over the photon's wavelength.

In the last chapter, Plank's constant defined the size of space as if it were smaller, atoms would be smaller and if it were larger, quantum effects would be more evident. Why then does the basic unit of energy also define the size of space? Current physics can't explain why what defines the smallest unit of distance also defines the smallest unit of energy.

In this model, Planck's constant is the basic energy unit because there is a core network process that sets values in a transverse circle whose number of nodes defines Planck's constant. The last chapter defined distance as the number of node-to-node transfers, so the smallest distance is that between two nodes, which is a Planck length in physics. If each node set a planar circle of neighbors whose number defines its circumference, the circumference of that circle defines its radius which is by definition the smallest distance of space. Thus, *the number of nodes in a transverse circle defines the basic energy unit and the number of nodes in a planar circle defines the size of space*.

If the quantum network is symmetric, transverse and planar circles will contain the same number of nodes. So if Planck's constant reflects the transverse circle size that defines the smallest unit of energy, it must also define the planar circle size that defines the smallest unit of space. In network terms, the basic units of energy and space depend on the *quantum network density* that defines the number of

[6] Let one photon be a quantum process shared over the nodes of its wavelength. Let h represent that process as energy, E be the photon processing rate at the node per cycle and λ be the number of nodes in the photon wavelength. Since the processing is shared between λ nodes, so is the energy h, so the photon processing rate at the node $E = h/\lambda$. If f is the number of quantum cycles each node takes to complete a quantum process that can run in one node in one cycle, then $f = 1/\lambda$. The Planck relation $E = h.f$ then follows. Note that this describes quantum units. To get our energy $\mathbf{E}$ in per second terms one must multiply E by c, the speed of light that reflects the quantum grid cycle rate of 10^{43} cycles per second, so $\mathbf{E} = h.c/\lambda$. In this case our frequency $\mathbf{f} = c/\lambda$ giving the same result, which is $\mathbf{E} = h.\mathbf{f}$ in our units.

neighbor connections each node can have in a circle around it. Planck's constant defines both space and energy because it derives from the *quantum network density* that creates both.

3.4. QUANTUM PROCESSING SPREADS

We know how a physical wave spreads but how does a processing wave spread on a network? According to quantum theory, quantum waves spread at the speed of light after they start but that theory doesn't say what is spreading or why it does so. If a quantum wave is a processing wave, it will spread at one node per cycle which as concluded earlier, is the speed of light. How then can a network "spread processing"? The computing method now proposed is called *instantiation,* a method that essentially allows a server process to run independently at many locations. Note that while the quantum no-cloning theorem (Wootters & Zurek, 1982) says that *we* can't copy quantum states, *the quantum system* that made them in the first place can easily do so. In this sense, nature may be the ultimate copy machine.

3.4.1. Light spreads forward

According to quantum realism, quantum processing put on the grid immediately spreads out in all directions, like ripples on a pool but in three dimensions. If a photon is a Planck process shared among the nodes of its wavelength, they in turn will also pass it on in every direction at one node per cycle, i.e. the speed of light. *Huygen's principle*, that light is a wave spreading with each point a new wave source, then follows from the nature of the quantum network. It follows that a light "ray" isn't a particle traveling a linear path but a wave spreading in all directions at the same time, and it is this wave that goes through both Young's slits at once.

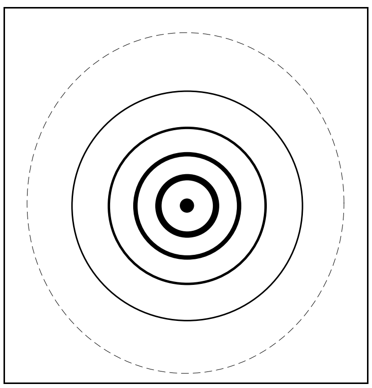

Figure 3.12. Pond ripples spread

Why then does light travel in a forward direction rather than just spreading out equally? It is as Huygen explained, because the wave has a "front" and a "back". In our terms, the nodes at the wavelength front started after those at the back, so they are just starting to run the Planck process when those at the back are just finishing it. If the network passes on the processing of each node in all directions, what spreads backwards is cancelled but what goes forwards isn't. The wave front moves *forward* due to the processing *sequence* of the photon wavelength, just as happens for a water wave.

Gauss noted that when a pebble drops in a pool, the initial energy spreads out in ripples of decreasing strength such that the *energy flux* per ripple is constant, but for friction. As shown in Figure 3.12, each ripple is the same energy spread out over a larger circle. This principle applied to the three-dimensional "ripple" of light is that the *processing flux* is constant and there is no friction. That a quantum "flux" spreading on a sphere surface reduces power as an inverse square of distance gives the inverse square laws of electricity, magnetism and gravity. It also predicts that processing values cancel at the node as fields do at a point[7] and that processing is passed on every cycle at the speed of light, as fields propagate. The next chapter attributes all the fields of physics to one quantum field.

3.4.2. Instantiation

Dynamic processing can spread on the quantum network by instantiation, an object orientated design method that allows screen objects to download processing from a source class. For example, if many screen buttons look and work the same, there is no point repeating the same code for each. It is easier to write a common *program class* and *instantiate* that code for every button. They must then look

[7] If charge 1 has electric field E_1 and charge 2 has electric field E_2, the electric field at any point $E = E_1 + E_2$

and act the same because they are *instances* of the same source process. This logic works for any screen object, like a drop-down menu or a mouse-over pop-up.

Quantum instantiation works the same way except that quantum processing is dynamic, so it also spreads on the network every cycle. Each instance, once started, begins the process of completing a transverse circle by accessing the photon server every cycle. A photon can then be envisaged as a *spreading cloud of quantum instances that pass their processing on to their neighbors every cycle*.

3.4.3. What is a photon?

In this model, a photon "exists" as processing running on the quantum network regardless of how it is distributed. Whether a photon's quantum wave is just starting at a point or spread out larger than a galaxy doesn't matter *as long as it runs*. What exists is neither quantum states nor physical states but processing that never stops and is in our terms, immortal. To say that a photon *has* wave function is to maintain the stubborn illusion that it is a *thing* with a wave *property*. In quantum realism, *the photon is the quantum wave* and the "particle" we see is just a *view* created by a physical event. We observe a particle but what creates that view is the photon quantum wave. If "*all the world's a stage*", then classical mechanics describes the stage while quantum mechanics describes what is going on backstage.

A physical realist might ask "*If a photon is a cloud of instances that can go through both Young's slits at once, which one is the photon?*" The question again betrays the assumption that a photon is a constant physical thing. Physical realism supports this view but quantum theory doesn't.

We see a photon hit a screen at a point, like a particle, but that it traveled that way is just an assumption tacked onto the facts. Knowing how a photon arrives isn't the same as knowing how it travels. Quantum theory tells us that photons *travel* as quantum waves but *interact* as point particles. Its critics couldn't fault this logic because there is no fault. What can travel like a wave but arrive like a point particle? The next section suggests that a processing wave can.

3.5. QUANTUM PROCESSING RESTARTS

Quantum theory says that quantum waves spread until they collapse in a physical event but what is *quantum collapse*? How does a quantum wave that can spread over a galaxy *instantly* "collapse" to a point? All we know is that nothing physical can do this.

3.5.1. Hidden variables?

Einstein, like Newton, believed that a photon particle traveled a fixed path from its start to hit a screen at a point, so when quantum theory declared that where the photon hit the screen was random, and the data agreed, he had two options: either quantum theory was *incomplete* or there were *hidden physical causes*:

"This is the fundamental problem: either quantum mechanics is incomplete and needs to be completed by a theory of hidden quantities, or it is complete and then the collapse of the wave function must be made physically plausible. This dilemma has not been solved until today, but on the contrary has become more and more critical." (Audretsch, 2004) p73

The problem Einstein raised still haunts physics today, as his attempt to find *hidden physical variables* to explain the facts failed and attempts to make quantum collapse "*physically plausible*" have also failed It has become clear that the rules of the quantum world defy those of the physical world.

The fact that no hidden physical variables have been found and that no attempt to make quantum theory physically plausible has worked is yet another failure of physical realism. In quantum realism, quantum theory is neither incomplete nor physically plausible. It isn't incomplete because it always works and it isn't physically plausible because nothing physical can do what it does. A quantum world that *generates* physical reality has no need to follow the rules of what it creates, so physics will never solve this dilemma until it rejects physical realism.

3.5.2. Quantum waves restart

If a photon is a spread-out wave, as quantum theory says, how can it arrive at a point? A wave should hit a barrier as a smear but a photon hitting a screen gives a dot instead. Radio waves are many meters long and so should take time to arrive, even at light speed, but they don't. If they did, in the delay between a wave front's first hit and the rest arriving, the tail could hit something else. One photon could hit twice which it never does! A physical wave delivers its energy of its entire wavelength so how does a quantum wave deliver *all* its energy *instantly* at a point? As Walker says:

> "*How can electromagnetic energy spread out like a wave … still be deposited all in one neat package when the light is absorbed?*" (Walker, 2000) p43

The fact is that physics doesn't know how a quantum wave collapses to a point in a physical event:

> "*After more than seven decades, no one understands how or even whether the collapse of a probability wave really happens*." (Greene, 2004), p119

Einstein didn't like quantum collapse because it implied faster than light travel. He argued that if a photon is a wave that spreads as quantum theory says:

> *Before* the photon hits a screen, its wave function exists at points A or B with some probability but *after* it is entirely at point A say not at B. The moment A "knows" it is the photon then B "knows" it isn't. Now as the screen moves further away, eventually A and B could be in different galaxies but if the collapse is *immediate,* how can this be? That two events *anywhere* in the universe are *instantly coordinated faster than light* contradicts special relativity.

In quantum theory, quantum waves are waves that spread to any size then collapse to a point when observed. Nothing physical can do this but processing spreading on a network can overload a node, giving reboot that:

a. *Is irreversible*. A reboot can't be reversed.

b. *Conserves processing*. The processing before and after a reboot is the same.

c. *Allows change*. A reboot can re-allocate processing in potentially new ways.

When a photon wave arrives at a screen, the extra processing is expected to overload nodes that are already maximally occupied with the screen matter. This will restart the photon server supporting the quantum wave. If many nodes reboot, the first to access the photon server will succeed. If a *parent server* maintaining many *child instances* restarts for one node, it will immediately stop supporting all other instances, so they "disappear". *The collapse of the quantum wave function is then just the inevitable disbanding of child instances when a server process restarts*. A quantum wave of any size can instantly disappear, as if it never was, because it is a wave of processing instances, not a "thing".

When a photon hits a detector screen, what arrives isn't a lonely particle looking for a point to hit but a cloud of instances requesting action from nodes already busy with screen matter. When a screen node overloads, it requests the server to restart the process, and since one photon has only one server, only one such request can succeed. The *first* node to successfully request a server restart is where the *entire* photon restarts and that point becomes where the photon "hits" the screen.

How can a quantum wave that could spread over a galaxy *instantly* collapse to a point in it? When our computers change a screen point, the program doesn't "go to" the screen pixel to change it. It can change any screen point directly and likewise a quantum server is directly linked to nodes anywhere on the screen of space. The *node-to-node transfer rate* that defines the speed of light is irrelevant to the *server-client* link that governs quantum collapse. If the quantum wave is a processing wave, what troubled Einstein, that quantum collapse is *instant* regardless of distance, isn't a problem.

Seeing quantum entities as processing not material things changes everything. When two electrons collide and bounce apart, we assume that what leaves the collision is the same matter that entered it, but if the "collision" is a node overload and server restart, the "particles" that leave are actually brand-new creations just off the quantum press. The conservation of processing in the reboot maintains the illusion that a matter "substance" continues to exist but *physical events annihilate and create quantum entities* just as quantum theory says.

3.5.3. The quantum lottery

What decides *where* a photon hits a screen when it arrives? In quantum theory, the quantum wave defines the *probability* it will hit at any point but where it *actually hits* is a random choice from those probabilities. The probabilities are *exact* but the actual hit point *varies* with no known physical cause.

Quantum theory calculates the *probability* a photon will hit a screen point as follows:

a. The wave equation describes how the photon cloud spreads through both slits.

b. Given two paths to a screen point, positive and negative wave values add to a net result.

c. The net amplitude *squared* is the *probability* the photon will physically exist at that point.

Quantum theory then explains Young's experiment as follows:

The photon quantum wave spreads through both slits, then its positive and negative values add or cancel at the screen to give interference that affects the probability of where it hits.

All this quantum activity is seen as entirely imaginary so it doesn't really happen but in quantum realism, there really is a quantum wave that really does generate physical events. If a quantum wave is a processing wave and a physical event is a node overload that restarts the server, what decides that? Servers have many clients so a quantum server response to a client node reboot request could be:

1. *Access.* The server restarts its processing at that node, which denies all other nodes access to it and collapses the quantum wave. This then is a physical event.
2. *No access*. The server doesn't respond as it is busy elsewhere so the node drops the process and carries on. This then was a potential physical event that didn't happen.

Quantum collapse is random to us because it is a winner takes all lottery run by a quantum server we can't observe. When many nodes reboot, the first to initiate a server restart locks out the others and wins the prize of *being the photon*, leaving other instances to wither on the grid. *It follows that screen nodes with more server access are more likely to reboot successfully.*

Quantum theory defines its probabilities based on the *square* of the quantum wave amplitude because a quantum wave is a sine wave and the *power* of a sine wave is its amplitude squared. This power defines the *processing demand* that determines *access* to the photon server. That positive and negative quantum amplitudes cancel locally is an expected efficiency. *Nodes that access the server more often have a greater probability to successfully reboot and host a physical event*.

When many screen nodes overload at once, where a photon actually hits depends on server activity that is to us *random,* as quantum theory says. But quantum theory can deduce the *probability* of where a photon hits from the square of the quantum wave amplitude at each point because *the power of the quantum wave at a node defines its server access*. Quantum realism *derives* what quantum theory *declared* based on known data, so it describes Young's experiment in *server access* terms as follows:

a. The photon processing wave spreads instances through both slits.

b. If they reach the same node by different paths, positive/negative values cancel or add.

c. When many screen nodes overload and reboot, the net quantum amplitude *squared* defines the probability of *server access* that results in a physical event.

In Young's experiment, the photon server supports client instances that pass through both slits then interfere as they leave, *even for a single photon*. This interference alters the server access that decides the probability a node overload will succeed. The first screen node to overload and restart the server is where the photon "hits". If detectors are in both slits, both fire equally because both have equal server access. If a detector is in one slit, it only fires half the time because the server is attending to instances going through the other slit half the time. Table 3.1 interprets Feynman's summary of quantum mechanics (Feynman et al., 1977) p37-10 as a calculation of *server access*.

Table 3.1. Quantum theory as server access

Quantum theory	*Server access*
1. Existence. The probability a quantum entity *exists* is the absolute square of its complex quantum amplitude value at a point in space [8]	*1. Restart.* The probability a quantum entity restarts a server in a physical event depends on node access, which is the absolute quantum amplitude squared
2. Interference. If a quantum event can occur in two alternate ways, the positive and negative amplitudes combine, so they interfere[9]	*2. Combination.* If quantum processing can arrive at a node by alternate network paths, the positive and negative values combine, so they interfere
3. Observation. Observing one path lets the other occur without interference, so the outcome probability is the simple sum of the alternatives, so the interference is lost[10]	*3. Interaction.* Interacting with a quantum wave on one path lets the other occur without interference, so the probability of either path occurring is the simple sum of the alternatives, so the interference is lost

This model now answers questions like:

a. *Does the photon go through both slits at once?* Yes, photon instances go through both slits.

b. *Does it arrive at one screen point?* Yes, photon processing restarts at one screen node (point).

c. *Did it take a particular path?* Yes, the instance that caused the node reboot took a specific path.

d. *Did it also take all other possible paths?* Yes, other instances, now disbanded, took every path.

If quantum theory is literally true, a photon really is a "wave" that goes through both Young's slits but it arrives at a screen *point* because a physical event is a server restart triggered by *one node*. A photon as server processing never dies because it can be born again from any of its legion of instances. Quantum realism explains what physical realism cannot: how *one photon* can go through both Young's slits at once, interfere with itself, but still arrive at a single point on a screen. It can also explain a mystery of light that has baffled scientists for centuries.

3.6. LIGHT TAKES EVERY PATH

That light always finds the best path to any destination has puzzled thinkers for centuries. Hero of Alexandria observed that light always takes the shortest path but how does it know that path? It might seem obvious that it is a straight line but how, at each step, does light know what *straight* is?[11] How light always travels the best path to any destination has always been a mystery and it still is today.

3.6.1. A wave moves

How light travels to a destination depends on whether it is a wave or a particle. Newton explained why he rejected Huygens's wave view of light as follows:

---

[8] If Q is the quantum wave amplitude and P its probability, then $P = |Q|^2$ for one channel.

[9] If Q_1 and Q_2 are the probability amplitudes of two ways that arrive at one point then the total amplitude $Q = Q_1 + Q_2$. If $P = |Q_1 + Q_2|^2$, then $P = P_1 + P_2 + 2\sqrt{P_1 P_2} \cos(\theta)$, where θ is the interference phase difference.

[10] Now $P = P_1 + P_2$ with no interference term.

[11] By relativity, light doesn't always travel in a straight line, so "straightness" is not self-evident.

"*For it seems impossible that any of those motions … can be propagated in straight lines without the like spreading every way into the shadowed medium on which they border*." (Bolles, 1999) p192

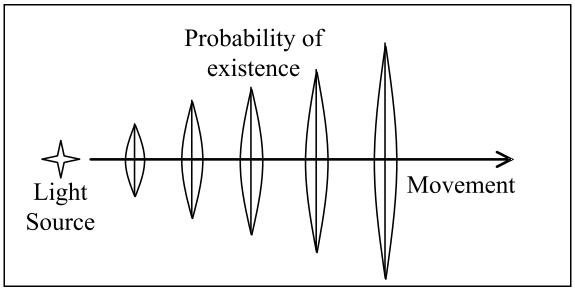

Figure 3.13. A *photon probability of existence*

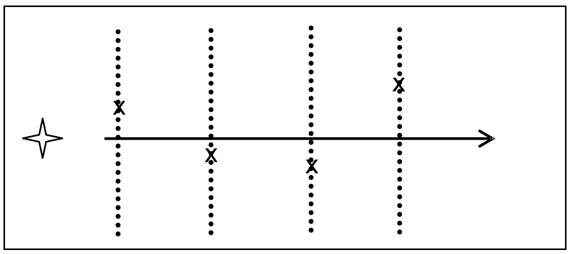

Figure 3.14. Detection of a photon of light

He was correct that if light moves as a wave, it should bend round corners as sound waves do, but it turned out that it does. In 1660 Grimaldi found that light does bend but less than sound as its wavelength is shorter. This changed the question to how can a spreading wave travel in a straight line?

According to quantum theory, where a photon is detected depends on the power of the quantum wave. Figure 3.13 shows how the photon wave power varies along its direction axis, where it's more likely to exist at the thicker sections. Detecting photons by screens at different distances confirms this, as the results aren't a perfect straight line but randomly spread about (Figure 3.14). A physical particle would have to travel in a zigzag path to explain this! When a photon moves, its maximum probability of existence is a straight line but the wave itself spreads in all directions!

If light only travels in a straight line *on average,* why are the straight lines of Greek optics so effective? The answer turns out to be not because light is made of particles but because it arrives at a single point, but first, let us continue the story.

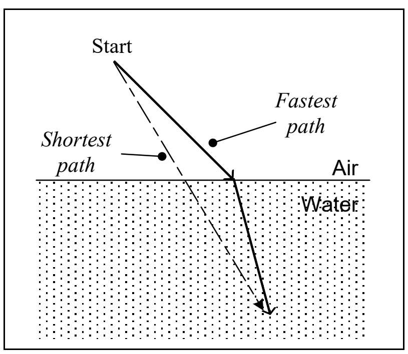

Figure 3.15. Light refracts

3.6.2. The physical law of least action

In 1662 Fermat amended Hero's law to be the path of least time, as when light enters water where it travels slower, it *refracts* to take the fastest path not the shortest path. In Figure 3.15, light takes the path that "bends" as it enters water not the shortest path.

To understand this, imagine the photon is a lifeguard trying to save a drowning swimmer as quickly as possible. The fastest path to the swimmer isn't the dotted straight line but the solid bent line because lifeguards can run faster than they swim, so it is faster to run further down the beach then swim a shorter distance. The dotted line is the shortest path but the solid line is the fastest and that is the path light takes (Figure 3.15). But again, how does a photon of light know *in advance* to take this faster path*?*

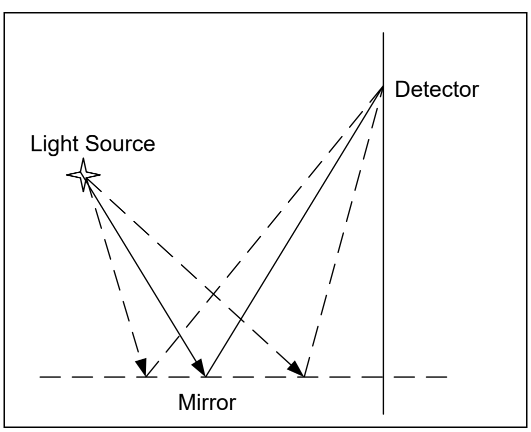

Figure 3.16. Principle of least action in optics

In 1752, Maupertuis generalized further that:

"*The quantity of action necessary to cause any change in Nature always is the smallest possible*".

Euler, Leibniz, Lagrange, Hamilton and others then developed the mathematics of this *law of least action,* that nature always does the least work, sparking a furious theoretical debate on whether we live in "*the best of all possible worlds*". Despite Voltaire's ridicule, how light always finds the fastest path remains a mystery today.

For example, light bouncing off the mirror in Figure 3.16 *could* take any of the dotted paths shown but by the principles of optics, it always takes the solid line fastest path. But as the photon moves forward in time to trace out a complex path, how does it at each stage pick out the fastest route? As Feynman says:

> "*Does it 'smell' the neighboring paths to find out if they have more action*?" (Feynman et al., 1977) p19-9

To say that a photon chooses a path *so that* the final action is less is to get causality backwards. That a photon, the simplest of all things, with no known internal mechanisms, always takes the fastest route to any destination, for any media combination, any path complexity, any number of alternate paths and inclusive of relativity, is nothing short of miraculous.

3.6.3. The quantum law of all action

Super-computers running a million-million cycles a second take millions of seconds (months) to simulate not just what a photon does in a million-millionth of a second, but in a million-millionth of that (Wilczek, 2008) (p113). How can these tiniest bits of the universe with no known structures make such complex choices? The answer now proposed is that "a photon" is not a particle following a line path but a cloud of processing instances.

Feynman's *sum over histories* method predicts how light goes from A to B by calculating all the paths, then choosing the one with the least action integral (Feynman et al., 1977) p26-7. It was accepted as a *method* because it works but not as a *theory* because a physical particle can't do that. Like the rest of quantum theory, it was a physical impossibility that just happened to predict perfectly.

Now suppose that Feynman's method works because it describes what actually happens. Photon instances do take *all available paths* and physical reality is decided down the line by the first one to trigger a server restart. The instance that *happens* to take the fastest path to a detector reincarnates as the photon in a physical event, making its path the one the photon took. The server restart makes all other instances disappear, like a clever magician removing the evidence of how a trick is done. Indeed, how else could the law of least action arise? A photon particle can't know in advance the best way to an unknown destination *before* it leaves, so the photon wave takes them all and the first to arrive restarts it in a physical event.

In a virtual reality, calculating and taking a path are the same thing. Knowing nothing in advance, the photon spreads instances down every path and the first to overload a detector becomes "the photon". What reaches a detector by the fastest route isn't a solitary particle magically knowing the best path in advance but a quantum ensemble that explores every path and disbands when the job is done.

It follows that every physical event comes from a myriad of quantum events. The quantum world tries every option and the physical world takes the best and drops the rest, so if this isn't the best of all possible worlds, it isn't for lack of trying.

The physical law of least action then derives from the *quantum law of all action* that:

Everything that can happen in physical reality does happen in quantum reality.

Gellman's quantum *totalitarian principle* that "*Whatever isn't explicitly forbidden must happen*" is equivalent to Feynman's "*Everything that can happen does happen*". Both imply that the photon takes every possible path and the instance that arrives first becomes "the path the photon took". Yet again, quantum realism explains what physical realism cannot.

3.7. QUANTUM SPIN

According to physical realism, quantum spin is a mathematical construct not what actually occurs but according to quantum realism, *quantum spin really happens*.

3.7.1. The curious case of quantum spin

Quantum spin is so strange that when Pauli first proposed it, he wasn't believed:

"*… the spin of a fundamental particle has the curious feature that its* ***magnitude*** *always has the* ***same*** *value, although the direction of its spin axis can vary…*" (Penrose, 1994) p270

A physical object like the earth spins in a *rotation plane* around an *axis of rotation* (Figure 3.17), so its spin on another axis is less than its total spin. If the spin axis is unknown, one must measure spin on three orthogonal axes to get the total spin. So that one can get the *total* spin of a quantum entity from *any axis* makes no sense in physical terms.

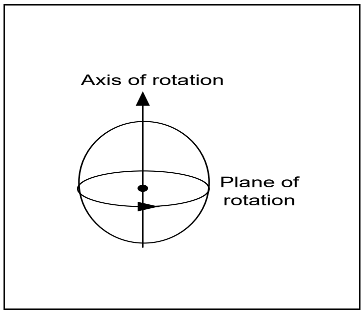

Figure 3.17. Classical spin

In quantum realism, a photon gives all its spin on any axis for the same reason that measuring either of Young's slits gives all the photon. A physical event is an all or nothing restart that gives the entire photon, including all its spin. The spin result for a photon is, as expected, one quantum process in radians, or Planck's constant in radians[12].

Imagine a coin spun on a table too fast to see its spin direction so the only way to see if it is clockwise or anti-clockwise is to touch it, after which it spins again, again too fast to see so it could spin either way. Spin is a basic property of *every* quantum entity because quantum processing spreads not only in linear directions but also in angular directions.

3.7.2. Quantum directions

Physical space as a surface within a higher dimensional *quantum space* gives quantum directions that aren't physical. In current physics, light vibrates into an imaginary dimension at right angles to its *polarization plane* but in quantum realism, light really does vibrate in a quantum direction that doesn't exist in our space. The amplitude of a light wave is at right angles to its polarization plane, setting values in a transverse circle that we cannot see.

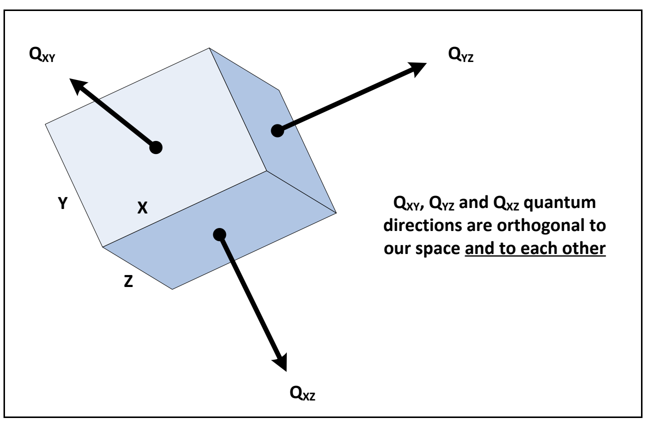

Figure 3.18. Quantum directions

One might think that one extra dimension adds one quantum direction but it isn't so. The dimensions of our space allow three orthogonal polarization planes that give three orthogonal quantum directions. Mathematics agrees that adding a fourth dimension to space gives three *quantum directions* not one[13], all at right angles to each other (Figure 3.18). This lets light at a point vibrate in three ways, at right angles to the three polarization planes through it.

Light moving on an axis can polarize in two ways called vertical and horizontal, where a filter that blocks vertical polarized light doesn't block horizontal polarized light and vice-versa. This is because light traveling in a direction has two different quantum directions to vibrate into. These are at right angles *to each other,* so what blocks one vibration doesn't block the other.

[12] Spin is expressed in Plank's reduced constant of $\hbar = h/2\pi$ (in angular radians).

[13] If physical space has dimensions (X, Y, Z), quantum space has dimensions (X,Y,Z,Q), with Q a fourth quantum dimension. Physical space has three planes XY, XZ and YZ but quantum space adds three more planes XQ, YQ and ZQ, so a photon vibrating into quantum space can do so in three orthogonal planes.

3.7.3. Spin in four dimensions

The above explains what happens when light meets a filter on an angle. Experiments show that a filter at an angle to the polarization plane of light *reduces* the light that gets through but still lets some photons through *entirely*. A filter at bigger angle to the light polarization lets fewer photons through, so a filter at 81º to the polarization plane lets only 10% of the photons through but some still get through entirely. How can a photon pass *entirely* through a filter that mostly blocks it? The answer now proposed is that quantum spin works in four dimensions.

To recap, spin in general involves a:

a. *Rotation axis.* Around which the spin occurs.

b. *Rotation plane.* In which the spin occurs.

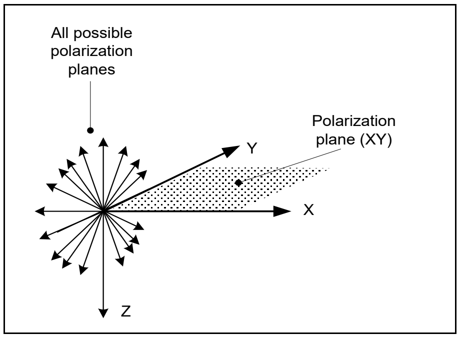

Figure 3.19. Polarization planes

Imagine a spinning propeller that rotates round an axis into the rotation plane that we see from the front. From the front, the blades rotate into the vertical and horizontal but the axis is just a point. From the side, the axis line is seen but the blade "disappears" as it spins into an unseen depth dimension.

Spin in four dimensions works like spin in three but with more options. If a photon *spins on its movement axis* as a bullet does, it spins into all the planes that cut its movement axis (Figure 3.19). This allows it to pass through a filter on an angle to its polarization plane. But as it spins, its quantum amplitude direction doesn't change because it isn't on the rotation plane[14]. So when a vertically polarized photon spins into the horizontal plane it disappears entirely, like a piece of paper on edge that can't be seen. As a photon spins on its movement axis, its amplitude varies according to angle. The quantum amplitude of a spinning photon appears and disappears like a propeller seen from the side. Some light gets through a filter on an angle because its amplitude projects into the planes that cut its movement axis according to angle[15].

Why then do some photons pass *entirely* through a filter on an angle? Again, it is because physical measurement is an all-or-nothing affair. The filter reduces the *probability* that instances get through a filter but if one does and is detected, the entire photon restarts at the point. The entire photon gets through a filter for the same reason that a screen point registers the entire photon. A physical event always delivers "the photon" because it restarts *all* the quantum processing that is the photon.

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[14] The Planck transverse circle already turns around the X axis into the YQ plane, but the photon can still spin in the YZ plane. This swaps its Y and Z values while leaving Q and X unchanged. Q remains perpendicular to XY, so as Y and Z swap it becomes invisible, as it has no extension orthogonal to the XZ plane.

[15] If Q is the quantum amplitude it reduces as Q.Cos(θ°) as it spins, where θ° is the angle from the polarization plane. So at a 90° angle it has no value as Cos (90°) = 0.

3.8. PHYSICS REVISITED

If a photon isn't just a wave but a processing wave, a photon can travel like a wave but still arrive at a point like a particle because processing can restart. A *quantum processing model of light* lets us revisit some well-known problems of physics.

3.8.1. Superposition

According to quantum theory, every photon goes through both Young's slits at once in a *superposition*. While solving a normal equation gives one solution that satisfies its conditions, solving the quantum wave equation gives a set of solutions, each of which is a physical event with a known probability. These *orthogonal solutions* evolve over time as the wave spreads but at each moment only one can occur as a physical event. The mathematics has the strange feature that given any two solutions, their linear combination is also a solution[16], but while single solutions match familiar physical events *these combination solutions never physically occur.* It is in just such a combination that one photon goes through both Young's slits at once. That quantum solutions can superpose underlies the mysterious efficacy of quantum theory.

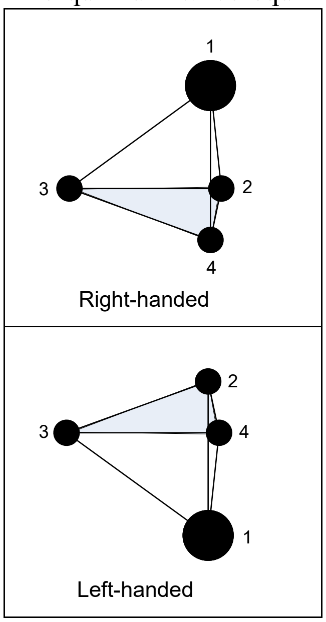

Figure 3.20. Ammonia molecule states

Not only photons can superpose, e.g. ammonia molecules have a pyramid shape (Figure 3.20) with a nitrogen atom apex (1) and a base of hydrogen atoms (2, 3, 4). This structure can manifest in either right or left-handed forms but to turn a right-handed molecule into a left-handed one, a nitrogen atom must pass through the pyramid base, which isn't physically possible (Feynman et al., 1977) III, p9-1. Yet in quantum theory, if two solutions are valid then so are both at once. This explains how an ammonia molecule can be left-handed one moment and right-handed the next, *even though it can't physically change between these states*. To call superposition ignorance of a hidden physical state is to misunderstand it, as superposed quantum currents can flow both ways round a superconducting ring at once even though physical currents would cancel (Cho, 2000).

In quantum realism, superposition is quantum processing simultaneously spreading to two or more outcomes regardless of their physical compatibility, so when a photon wave spreads through two slits in Young's experiment, it literally *half-exists* in both. If the photon is later observed in a physical event, that photon restart is based on a specific instance. Superposition is physically impossible but is just business as usual in the quantum world.

3.8.2. Schrödinger's cat

Schrödinger found superposition so odd he tried to illustrate its absurdity by a thought experiment. He imagined his cat in a box with a radioactive source that could randomly emit a photon to trigger a deadly poison gas. In quantum theory, a photon plus detector is a quantum system that both detects and doesn't detect the photon until observed. If the box is also a quantum system it also superposes and the poison is both released and not, so the cat is in an alive-dead superposition until Schrödinger opens the box. But how can a cat be alive and dead? Or if cats can't be alive and dead, how can photons exist and not exist? Or if photons can do this but cats can't, when does the superposition stop?

In quantum realism, a photon wave spreads on the network until an overload restarts it, in what we call an "observation". Observing the world *formally causes* what we see but it isn't a *sufficient cause* as

[16] If $\boldsymbol{\Psi}_1$ and $\boldsymbol{\Psi}_2$ are state solutions of Schrödinger's equation then $(\boldsymbol{\Psi}_1 + \boldsymbol{\Psi}_2)$ is also a valid solution

every observation is a mutual interaction between parties. Quantum realism isn't that we alone are dreaming the physical world but that our *interaction* with the quantum world generates a physical view.

If quantum collapse is a quantum network overload, then *any* overload can cause it not just those that involve us, *so the quantum superposition collapses immediately the detector records a photon*. It then releases the poison regardless of whether Schrödinger sees it or not. Likewise, the cat interacts with the poison whether Schrödinger sees it or not. Before opening the box, *Schrödinger* doesn't know whether the gas was released but *the cat does* (or did). Quantum superposition stops the moment *any observation* occurs. It is not delayed until **we** interact with the system. In quantum realism, *quantum collapse occurs with any observation, not just those that involve human eyes or instruments*.

We aren't the only observers of physical reality. If every physical event is an observation, when we observe a photon it also "observes" us. The universe is a virtual reality not a dream just for us, so quantum events were generating physical events long before our species came along. *Quantum realism implies that everything is observing everything else in a fundamental sense*.

3.8.3. Delayed choice experiment

That photons travel about a foot per nanosecond allows a *delayed choice* two-slit experiment. Two detection options are used, either the usual screen or two telescopes that focus on one slit or the other (Figure 3.21). The trick is that the choice of which to use is made *after* the photon passes the slits, when the screen is either quickly removed or not. If the screen is used, the result is the usual interference so the photon passed though both slits but if the telescopes are used only one fires, so the photon took one path or the other. It follows that a detector turned on *after* the photon passed the slits decides the path it took *before* that:

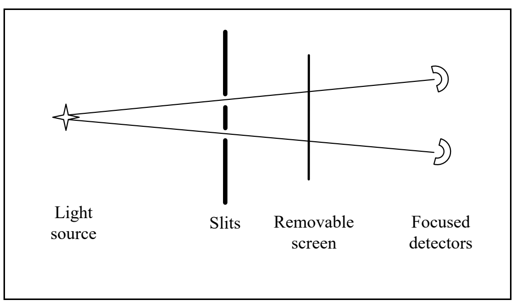

Figure 3.21. Delayed choice experiment

"*It's as if a consistent and definite history becomes manifest only after the future to which it leads has been settled*." (Greene, 2004) p189

If an observation made *after* a photon travels a path decides the path it took *before* that, physical realism must conclude that the future can affect the past! The distances involved are irrelevant, so a photon could travel from a star for a billion years then decide *when it arrives at earth* if it physically traveled via galaxy A or B. As Wheeler says:

> "*To the extent that it {a photon} forms part of what we call reality… we have to say that we ourselves have an undeniable part in shaping what we have always called the past.*" (Davies & Brown, 1999) p67

That time flows backwards puts all physics in doubt but quantum realism concludes that the photon takes every path and chooses a physical event when it arrives. Computing calls leaving all processing choices until the last possible moment *just-in-time* processing and it lets point-of-sale systems base supply orders on what customers actually buy rather than historical estimates.

Applying this method to Young's experiment, photon instances go through both slits and if a screen is there they give interference but if it isn't there, they just carry on spreading until an instance registers a telescope to restart there. Since that instance went through one slit, we call that the photon's "path". If on the other hand the screen is left there, we conclude that the photon went through both slits. On the quantum level, swapping the screen in and out after the light goes through the slits doesn't matter at all because *the physical event that defines the path occurs on arrival*.

Every photon observation involves a specific instance whose path history becomes that of "the photon". Photon instances take every path until an observation restarts the photon, making its path the photon's *physical path*. According to physical realism, the *delayed choice* two slit experiment implies backwards causality but in quantum realism there is no time reversal and causality remains intact.

3.8.4. Non-physical detection

Quantum theory allows experimenters to detect an object without observing it physically in any way. This should be physically impossible but in our world it isn't. The setup to do this is shown in Figure 3.22. A light source shines on a beam splitter that sends half the light down *path 1* and half down *path 2,* so at this stage the detectors shown each fire half the time. Now a second splitter is added where the two paths meet that splits the light again, half to one detector and half to the other. Now detector 1 registers but detector 2 stays silent. Quantum theory explains this as follows:

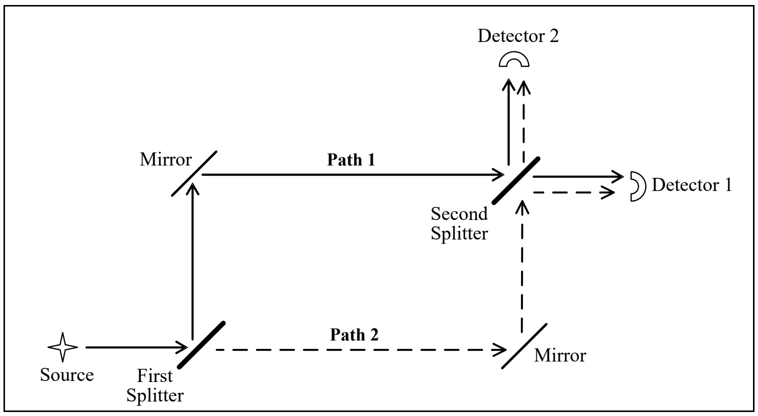

Figure 3.22. The Mach-Zehnder interferometer

As photon quantum waves evolve down the paths, each mirror or splitter delays the phase by half. The two paths to detector 1 have two turns so they are in phase but path 1 to detector 2 has three turns and path 2 has only one so they cancel at detector 2. Detector 2 never fires because the quantum waves from the two paths to it always cancel out.

This setup allows a very unusual result. If an object that registers *any* light is put on path 2, the previously silent detector 2 sometimes fires *without the object registering any light*. This never happens if path 2 is clear, so this setup can *prove* there is an object on path 2 without touching that object.

To recap, the results of this experiment (Kwiat et al, 1995) are:

1. With two clear paths, only detector 1 fires.
2. If a receptor blocks path 2, detector 2 sometimes fires without setting the receptor off.

This setup can *detect an object without physically observing it* (Audretsch, 2004) p29 and quantum theory explains how:

As photon quantum waves evolve down the paths, those on path 2 are now blocked by a receptor that registers light half the time. Since the path 1 waves to detector 2 no longer cancel out, it fires a quarter of the time even though no light is registered on path 2. The other quarter of the time the path 1 light registers on detector 1. Detector 2 firing proves there is an obstacle on path 2.

To show how strange this is, suppose that unknown to the experimenters, path 2 contains a bomb so sensitive that even one photon will set it off. If they send one photon down the system and get lucky – detector 2 fires to prove the bomb is there. The bomb has been detected without physically touching it in any way, though this is a bad bomb detection technique because half the time it sets the bomb off!

Non-physical detection supports quantum theory but again physical realism can't explain it at all. If a physical thing is out there, how can we register it without physical contact? How can one photon detect a bomb on a path that it didn't take?

In contrast in quantum realism, quantum theory is literally true. The photon instances travel along four paths to the two detectors, where Table 3.2 shows the results. Non-physical detection occurs when an instance that travels along path 1 to detector 2 registers a physical event. This result confirms that quantum waves exist but physical realism has no explanation for it at all.

Table 3.2. Non-physical detection

Path	Probability	Result	
		No Obstacle	**Path 2 Obstacle**
Path 1 to Detector 1	25%	Detector 1 fires	Detector 1 fires
Path 2 to Detector 1	25%	Detector 1 fires	Path 2 registers light
Path 1 to Detector 2	25%	Detector 2 doesn't fire	*Detector 2 fires but path2 doesn't register any light*
Path 2 to Detector 2	25%	Detector 2 never fires	Path 2 registers light

3.8.5. Quantum entanglement

Quantum entanglement is one of the great mysteries of quantum theory. When a Cesium atom gives off two photons in opposite directions, quantum theory says they become *entangled* and evolve as one system with net zero spin, even though each photon can still randomly spin up or down. According to quantum theory, however far apart they get, if one photon is spin up the other *must* be spin down. Yet if both spin *randomly,* how does each *instantly* know to be the opposite of the other?

Einstein called this "*spooky action at a distance*" and devised a thought experiment to deny it (Einstein, Podolsky, & Rosen, 1935). When a test was devised, based on Bell's inequality, it showed that entanglement occurs *even when the photons are too far apart to exchange a signal at the speed of light* (Aspect, Grangier, & Roger, 1982). This was one of the most careful experiments ever done, as befits the ultimate test of quantum theory, and it proved quantum theory right yet again, despite there being no physical means for it to occur!

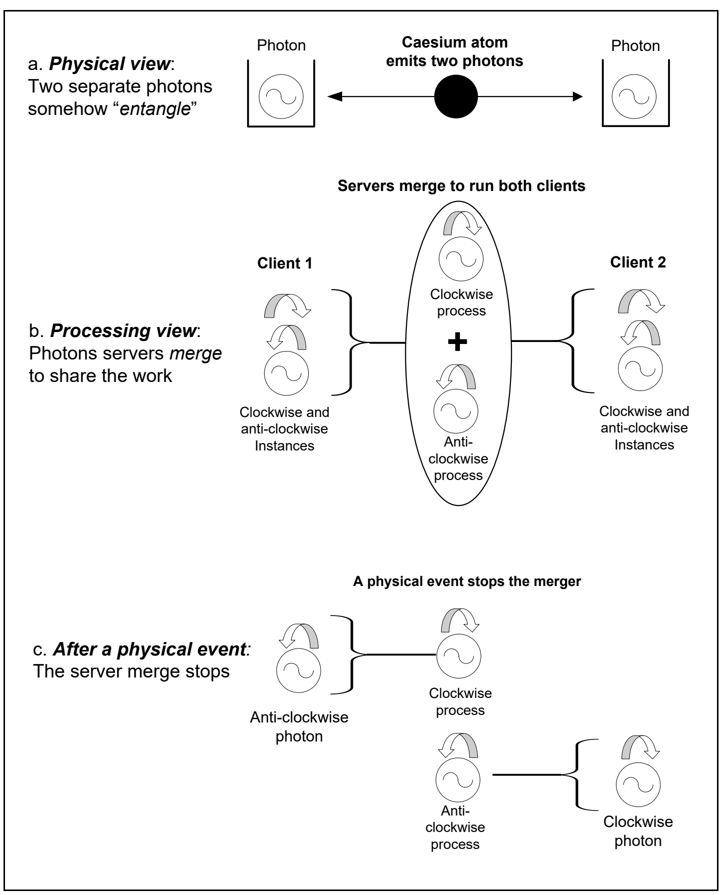

Figure 3.23. Entanglement as merged processing

Two photons heading in opposite ways are physically apart so if each spins randomly, as quantum theory says, *why can't both be up or both be down*? What connects them if not physicality? Quantum theory requires the initial zero spin to be conserved, but gives no clue as to how. Nature *could* conserve spin by making one photon spin up and the other down from the start, but apparently this is too much trouble. It lets both photons have either spin until one photon's spin is registered, then *instantly* adjusts the other to be the opposite *regardless of where the photons are in the universe*. Entangled states that defy physical realism are now common in physics (Salart, Baas, Branciard, Gisin, & Zbinden, 2008).

Quantum realism *explains* what quantum theory *describes* as follows. The two photons emitted by a Cesium atom begin a node reboot that reloads two photon processes at once to *entangle them,* and the initial net spin of both photons is zero. To us, two photons leave the Cesium atom (Figure 3.23a) but the quantum situation is more complex: the two photon servers each handle *half of both photons* rather than each handling one, even though they set of in opposite directions. What appears to be us as two physical photons are at the quantum level two hybrid photons handled by both photon servers (Figure 3.23b).

What entangles isn't the physical photons but their processing, which is that of a clockwise photon and an anti-clockwise photon. The photon going left is run by two servers as is the one going right. The photons are entangled at the quantum level not the physical level. When one of the photons is observed, the instance that generates that physical event randomly restarts one photon server, leaving the opposite spin server to run the other photon (Figure 3.23c).

To recap, photons entangle when their processing merges. From that point, two servers service both "photons" jointly until another physical event starts things anew. The entangled photons look like photons and act like photons but each is two "photon halves" in server terms. Spin is conserved because the start and end processing must be the same, just as quantum mechanics requires.

Entanglement effects are non-local for the same reason quantum collapse is, that client-server relations ignore the node-to-node speed of light transfer limit. By analogy, when pixels are produced on a screen, the processing doesn't have to "go to" a point to do that. It can change any screen point directly and likewise photon servers act directly no matter how far apart entangled photons are on the "screen" of our space.

Entanglement also underlies super-conductivity where many electrons entangle and again the server processing merges, so every electron is a processing hybrid of all the electrons. Electrons "move" with no resistance in a superconductor because each one in effect exists everywhere in the metal. In Bose-Einstein condensates any number of quantum processes can merge in this way.

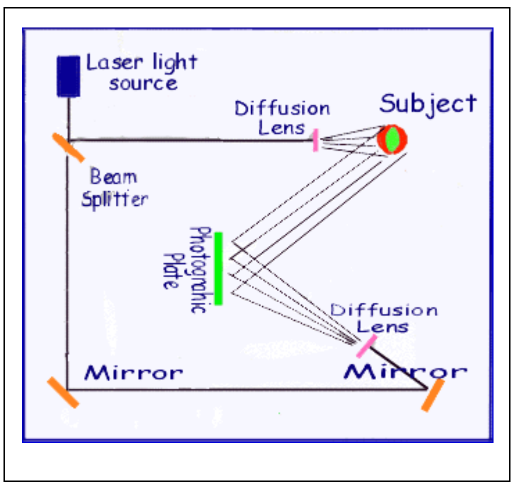

Figure 3.24. Producing a hologram

3.8.6. The holographic principle

Our eyes see depth because light from different distances arrives slightly out of phase. Photos that only store light intensity don't show depth but holograms can show 3D images because they store the phase differences that encode it. A hologram is made by splitting laser light and letting the half that shines on the object interfere with a matched reference half to give an interference pattern (Figure 3.24). Light later shone on that flat pattern recreates the original 3D image as a holograph.

The *holographic principle* is that everything we know about the universe is essentially a hologram, or more precisely:

> *Everything physically knowable about a volume of space can be encoded on a surface surrounding it* (Bekenstein, 2003).

This principle, which is widely accepted in physics, is that all the information we receive about the world can be encoded on a flat surface just like a hologram. The information in a space seems to depend on its volume but if one were to pack smaller and smaller memory chips into a space to get more information in it, the end result would be a black hole whose entropy depends on its surface area not its volume. Since black holes have more entropy than anything else for the same volume it follows that the information about *any* physical object can be encoded on a two-dimensional surface. The holographic principle is maintained by the behavior of black holes (Bekenstein, 2003).

Quantum realism interprets the holographic principle as follows. A virtual world must be observed from some direction so the act of observing uses one of the three dimensions of space. If an observation is an information transfer, as proposed here, that leaves only two dimensions to carry out the transfer, so the physical world registered at a point can always be painted on the surface of a sphere around it because that is the structure that delivers it. Quantum realism thus *requires* the holographic principle, and that this principle applies to our world supports quantum realism.

Does the holographic principle imply that our universe is really two-dimensional? That our world *presents* as a 2D image only means that one dimension must deliver it across two dimensions but space still has three degrees of freedom. The holographic principle implies that physical reality is virtual not that it is two dimensional. It is a result of how physical reality *presents* not how space *operates*.

Equally to say that the physical world is "like a hologram" is misleading, as this is no Star Trek hologram we can enter and leave at will because our bodies *are* its images. If this "hologram" ever switched off, the continuity of physical reality would stop and the only way to recover it would be to start again from scratch.

3.8.7. The uncertainty principle

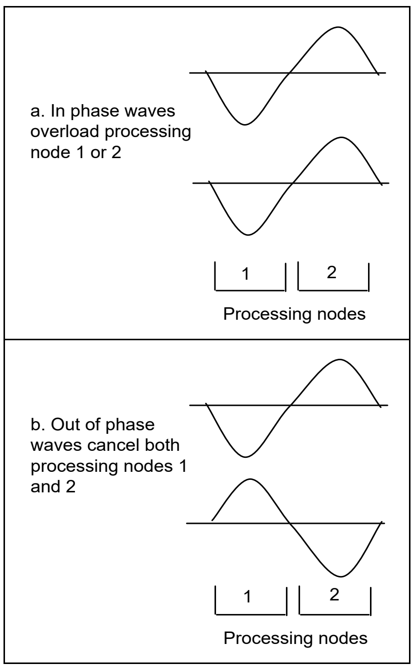

Figure 3.25. Waves interacting

Heisenberg's uncertainty principle is that one can't know both a quantum entity's exact position and momentum at the same time. These facts are said to be *complementary,* to be separately knowable but together unknowable. This isn't expected of physical objects but quantum theory insists that measuring either one fully denies all knowledge of the other entirely.

This result, which has been verified experimentally, can be understood if measurement is an information transfer:

"*… a measuring instrument is nothing else but a special system whose state contains information about the "object of measurement" after interacting with it:*" (Audretsch, 2004) p212

Quantum realism adds that every measurement is an overload interaction between quantum waves. Figure 3.25 shows a simple case of two waves interacting to overload in two nodes:

a. If they are *in phase,* one node overloads to give a position exactly but the wavelength is unknown.
b. If they are *out of phase,* both nodes cancel to define the wavelength exactly but there is no position information.

The interaction can reveal position or wavelength but not both, with no repeats. If the result gives position there is no wavelength data and if it gives wavelength there is no position data. In both cases, the observed wave has given all the information it has to the interaction. It follows that one wave "observing" another can give position or wavelength information but not both.

The quantum uncertainty principle follows from the nature of wave interactions based on De Broglie's equation of momentum and wavelength[17]. The information change in any photon interaction can't be less than a quantum process so position plus momentum can't be less than Planck's constant[18].

[17] If p is momentum, λ is wavelength and h is Planck's constant, then $p = h/\lambda$

[18] Mathematically $\delta x.\delta p \geq \hbar/2$ where x is position, p is momentum and $\hbar$ is Plank's constant in radians.

3.9. REDEFINING REALITY

If our world regularly does what isn't physically possible, why is physical realism still accepted? Time and again, quantum theory predicts a result that can't physically occur but still does, whether it's a photon traversing two slits at once or traveling many paths. The data doesn't lie but we, it seems, are happy to believe in a theory that doesn't work! The logic seems to be "*Physical realism must be true because there is no scientific alternative*". Quantum realism is now that alternative but it comes at the price of redefining reality. Physics can either accept that the physical world does impossible things or redefine reality to be quantum. The many-worlds fairy tale is an example of the first choice.

3.9.1. The many-worlds fairy tale

In quantum theory, quantum collapse is *random* and the evidence is that when a radioactive atom emits a photon is unpredictable. A random event by definition has *no physical history that can explain it* and in quantum theory, *every* physical event involves a random quantum collapse, contradicting the claim that *all* physical results are caused by prior physical acts.

That every physical interaction involves a *random choice* clearly contradicts physical realism so in 1957, Everett proposed *many-worlds theory,* that every quantum choice spawns *a new universe*. Now if an electron anywhere in the universe chooses to be say spin up, another universe magically arises in which it is spin down, so there is no choice. Everett's idea was first seen as absurd, as it is, but today physicists prefer it 3:1 over the Copenhagen view (Tegmark & Wheeler, 2001, p6). They believe that for fourteen billion years every photon that exists has created a new universe with its every act! With up to 10^{43} universes being created per photon per second, it isn't hard to see that the:

"… *universe of universes would be piling up at rates that transcend all concepts of infinitude.*" (Walker, 2000) p107.

For a scientist, this doesn't just offend Occam's razor, it outrages it. Do you believe that in the time it took to read this sentence, a billion, billion *universes* arose just from the light that hit your eyes? Current physics does because it is the only way to dismiss quantum randomness. Some now talk of the *multiverse* as a fact despite no evidence at all, based on the belief that *"It must be so"*.

In historical terms, many-world-theory essentially replaces the *clockwork universe* that quantum theory demolished last century with a *clockwork multiverse*. Attempts to rescue this zombie theory[19] by letting a finite number of universes repartition after each choice (Deutsch, 1997) only recovers the original problem, as what *chooses* which worlds are dropped? Yet why would the universe, like a doting parent with a quantum camera, want to store everything that *might happen*? *The many-worlds multiverse is truly a fairy tale for physicists* (Baggot, 2013).

3.9.2. Is science about physical things?

Physics today agrees that quantum waves aren't observable:

"*The full quantum wave function of an electron itself is not directly observable…*" (Lederman & Hill, 2004) p240

Nature's *firewall* separates us from quantum reality, as any attempt to observe a quantum wave collapses it to a physical event. That quantum theory is based on what can't be directly observed raises the question "*Is it really science?*"

The doctrine that only "*...what impinges on us directly is real*." (Mermin, 2009) p9 has been taken to imply that what we can't observe isn't real, so one can argue that:

[19] Zombie theories make no new predictions and can't be falsified. Like zombies, they have no progeny nor can they be killed by falsification, as they are already scientifically "dead".

1. Science should only describe physical reality, not imaginary things like fairies.
2. Physical reality is only what we can physically observe.
3. Therefore, science shouldn't describe what we can't physically observe!

If describing what isn't physical isn't science then quantum theory isn't science, yet it is the most successful theory in the history of physics! The flaw in the argument is that statement 1 is false because science is based on *predicting physical reality,* not what it describes.

The idea that science can only describe physical things is called *logical positivism,* a nineteenth century fallacy of science that predates quantum theory. Statement 1 above, that science must describe physical reality, is *physical realism masquerading as an axiom of science*.

Science is actually based on Locke and Hume's *empiricism*, that scientific theories must be *tested by physical reality*. Quantum theory is then a science because it *predicts* physical events, regardless of what it *describes*. There has never been a requirement that scientific theories must describe physical things e.g., gravity isn't a physical thing but Einstein's theory of gravity is science because it predicts physical effects. To reject any reference to the non-physical would deny the mathematics of complex numbers that physicists use every day.

Logical positivism has failed every discipline that tried it. *Behaviorism* tried to reduce psychology to physical acts until Chomsky showed it failed for language, and applying positivism to computing would ignore the human and social levels behind socio-technical systems like Twitter. In some ways, physics is the last bastion of the idea that only the physical is real, but yet again, it is failing.

Saying the physical is all there is ignores the observer but reality in a participative universe is an *observer-observed interaction*, so to ignore the observer is to ignore half of reality. *The observer is fundamental* because every science needs it, even physics as an observer triggers quantum collapse and relativity needs an observer frame of reference. Attempts to "ban" the observer from science don't work because the observer is inherent to our reality.

In quantum realism, the quantum world observing itself makes a virtual physical world, so the observer is the answer not the problem. Physical reality arises when an observer interrogates quantum reality as a game click gives a view so *the long-sought boundary between the classical and quantum worlds is the "click" of observation*. We see a *phenomenon* not the *noumenon* or "thing in itself" (Kant, 2002, p392) so calling physical phenomena real and quantum noumena unreal was the wrong turn that led physics into the current desert of physical realism. *All science is based on the observer*.

3.9.3. The quantum paradox

The quantum measurement problem arises from how quantum collapse and its effects occur. Quantum waves evolve in a deterministic fashion by Schrödinger's equation but when *measured* they collapse to a point for reasons unknown. The problem is that physics has deduced the probability set of that collapse but has no idea *what chooses from it*. It is as if a choice from nowhere decides every microscopic measurement. This problem was raised early last century and no progress has been made on the matter since:

"*The history of the quantum measurement paradox is fascinating. There is still no general agreement on the matter even after eighty years of heated debate*." (Laughlin, 2005) p49.

The measurement problem, in a nutshell, is that it doesn't conform with Aristotle's view that:

"*… the world consists of a multitude of single things (substances), each of them characterized by intrinsic properties …*" (Audretsch, 2004) p274

Two thousand years later, this vision of a world of things that cause other things still dominates thought, so why not apply it to quantum theory?

"*… why not simply accept the reality of the wave function?* (Zeh, 2004) p8

This didn't happen because quantum theory:

"*… paints a picture of the world that is less objectively real than we usually believe it to be.*" (Walker, 2000) p72.

In other words, quantum theory contradicts physical realism. In addition, if one accepts that part of quantum theory is real, then one must accept that all of it is.

"*… if we are to take ψ [the quantum field] as providing a picture of reality, then we must take these jumps as physically real occurrences too…*" (Penrose, 1994) p331

Schrödinger tried to explain quantum theory in physical terms but failed, as have all who have tried the same since. What quantum theory describes isn't physically possible: quantum states that disappear at will ignore physical permanence; entangled effects that occur instantly over any distance ignore the speed of light limit; and superposed states that co-exist in physical contradictions ignore physical limits. A quantum wave can spread across a galaxy then instantly collapse to a point but:

"*How can something real disappear instantaneously?*" (Barbour, 1999) p200

When Pauli and Born defined the quantum wave amplitude as a *probability of physical existence*, physics ceased to be about anything physical at all:

"*For the first time in physics, we have an equation that allows us to describe the behavior of objects in the universe with astounding accuracy, but for which one of the mathematical objects of the theory, the quantum field* ***ψ****, apparently does not correspond to any known physical quantity.*" (Oerter, 2006) p89

That quantum theory predicts physical reality gives the *quantum paradox,* that what isn't real physically predicts what is, so can the unreal cause the real? As one theoretical physicist says:

"*Can something that affects real events … itself be unreal?*" (Zeh, 2004) p4.

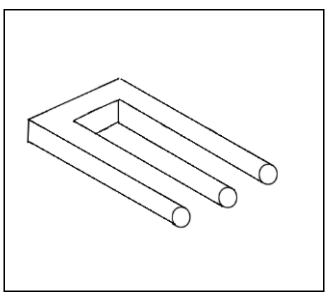

Figure 3.26. A paradox

For over a century, physics has faced this paradox like a deer in headlights, attracted by the quantum brilliance but afraid to abandon the orthodox stance of physical realism.

Paradoxes only disappear when false assumptions are exposed. For example, Figure 3.26 has two square and three round prongs depending on where you look which is impossible. The answer isn't a mystical "*square-round duality*" but to see that one line can't bound both a square prong and a round one at the same time. Likewise, the quantum paradox arises from the false assumption of physical realism, so when Penrose asks:

"*How, indeed, can real objects be constituted from unreal components?*" (Penrose, 1994) p313

the honest answer is that they can't. One might equally ask "*How can a purely physical world have random events?*" or "*How can a complete physical universe begin?*" A physics based on illogic builds paradox into its foundations but to do this is to institutionalize illogic and this isn't science. The logical way forward is to abandon the physical realism of Aristotle and accept that quantum reality creates physical unreality, based on the facts of physics.

3.9.4. A new realism

Bell's experiment tested the following *axioms* of current physics (D'Espagnat, 1979):

1. *Physical realism*. That "*there is some physical reality whose existence is independent of human observers.*" (D'Espagnat, 1979) p158

2. *Locality*. That no influence of any kind can travel faster than the speed of light.
3. *Induction*. That logical induction is a valid mode of reasoning.

The result showed that one or more of these assumptions *must be wrong.* If physical realism and induction are true, then locality must be wrong. If locality and induction are true, there can't be a real physical world out there. If physical realism and locality are true, then logical induction must be false. To this day, physics has not resolved this issue:

"*According to quantum theory, quantum correlations violating Bell's inequalities merely happen, somehow from outside space-time, in the sense that there is no story in space-time that can describe their occurrence*:" (Salart et al., 2008) p1

Quantum realism resolves the quantum paradox by changing the first two axioms as follows:

1. Remove the word "physical" from the first axiom so it becomes:

That there is a ~~physical~~ reality whose existence is independent of human observers

This permits a quantum reality to exist independent of human observers.

2. Add the world "physical" to the second axiom so it becomes:

That no <u>physical</u> influence of any kind can propagate faster than the speed of light.

This permits quantum collapse to occur instantly as server-client effects aren't physical influences, so Bell's results no longer contradict locality.

For example, a statement of scientific realism such as:

"*If one adopts a realistic view of science, then one holds that there is a true and unique structure to the physical universe which scientists discover rather than invent.*" (Barrow, 2007) p124

now becomes instead:

"*If one adopts a realistic view of science, then one holds that there is a true and unique structure to the ~~physical~~ universe which scientists discover rather than invent.*"

Removing "physical" from the first statement gives *quantum realism,* that science discovers rather than invents the true and unique structure of the universe, even though it isn't the world we see. If physical reality reflects quantum reality, physical laws come from quantum laws that aren't limited by their output. This new realism requires *new rules* based on quantum theory not physical mechanics.

Quantum theory describes waves spreading not billiard ball particles following linear paths so light does indeed take every path. It sees a physical event as a primal choice not an inevitable mechanic so randomness is real. And it calls the result an observation not a collision so observing is an inherent property of quantum reality. Hence just as an eye can't see itself seeing, we can't observe quantum reality because it is what creates the observation itself.

The resulting vision of a universe where everything observes, everything chooses and everything is alive is a far cry from the mechanistic universe usually portrayed by physics. Materialism was the mother of physics but as every child one day leaves its mother for a new reality, so physics must give up physical realism to adopt a new realism based on new facts.

3.9.5. The unmeasured reality

We assume the world is physically real because we see it as such. For the same reason, when people meet actors from their favorite TV soap opera for the first time, they often treat them like their onscreen persona. Likewise, we assume that what we see is reality not because it has been *proven,* as it hasn't, but because it is *self-evident,* as that is our bias:

"*Observers have to be made of matter…Our description of nature is thus severely biased: we describe it from the standpoint of matter.*" (Schiller, 2009) p834

That we *register* the world as physical doesn't *prove it is so*, but we accept:

"*… the dogma that the concept of reality must be confined to objects in space and time…*" (Zeh, 2004) p18

Yet science advances by questioning assumptions not sanctifying them. Quantum theory implies that behind what we see is quantum reality, of which Bohr said *we must not speak,* but since when was science about not asking questions?

And since quantum collapse occurs in an instant, entities are mostly between measurements:

"*Little has been said about the character of the unmeasured state. Since most of reality most of the time dwells in this unmeasured condition …the lack of such a description leaves the majority of the universe … shrouded in mystery*." (Herbert, 1985) p194

If entities exist mostly as spreading quantum waves, by what logic are their brief moments of collapse considered real? *Surely reality is what is there most of the time?* And if quantum waves cause physical reality, isn't saying that the unreal causes the real backwards logic? If one thing causes another, *surely reality is the cause not the effect?*

The current denial of quantum reality is doctrinal not logical, based on faith not facts. When atoms were first proposed, Mach denied they existed because they were unseen but today, we accept quarks that are never seen alone. Yet when quantum theory says physical reality is a set of possibilities, we cry "*Enough!"* and turn away. That the answer to life, the universe and everything is just a probability is a step too far. After two thousand years of scientific struggle, physics is ignoring its own conclusion that physical reality is a choice from unmeasurable quantum outcomes.

3.9.6. The quantum dragon

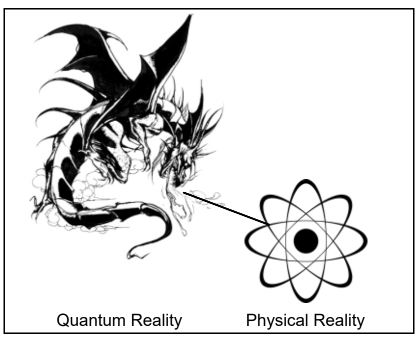

Figure 3.27. The quantum dragon

We see ourselves in the sunlight of rationality standing before the dark cave of quantum paradox, but as in Plato's cave analogy, it may be the other way around, that we are sitting in the darkness of physicality with our backs to the quantum sunlight, calling the shadows it casts on the wall of space real. Quantum theory and relativity have loosed the chains that bind, but who will turn and look? Einstein did but the quantum brilliance blinded him. Bohr did but his impenetrable Copenhagen suit revealed only his own reflection. The quantum light is currently quarantined behind a wall of arcane equations and the acolytes that harvest it must first *deny that it exists.* The first rule of the quantum club is that there is no quantum world, but calling its own best theory a theory of nothing is leading physics nowhere.

Table 3.3 contrasts how quantum realism and physical realism explain light for the reader to decide. Quantum theory today makes no more sense now than it did last century and the next hundred years will be the same unless it becomes a reality description. If the quantum world is *a great smoky dragon* (Wheeler, 1983), then the physical world is its smoke (Figure 3.27). *The quantum world is not a shadow world existing alongside physical reality but the real world whose shadow is the physical world we see*.

Table 3.3. Chapter 3 summary: Physical realism vs. quantum realism for light

Physical Realism	Quantum Realism
A photon is a "wavicle" that: a) Sets imaginary positive/negative values b) Moves as a sine wave, for an unknown reason c) Has the fastest speed possible, for an unknown reason d) Doesn't fade by friction, as a physical wave would e) Collides to give *all* its energy at a point, like a particle	*A photon is a quantum process* that: a) Rotates values at right angles to space b) Projects a sine wave because it is a circular process c) Transfers once per cycle as the maximum network rate d) Doesn't fade because the quantum network sustains it e) Restarts *all* its processing at a physical event point
Energy. A photon's *energy*: a) Decreases as its wavelength increases b) Increases as its frequency increases c) The increase is quantized for some reason	*Energy.* A photon's *processing rate per node*: a) Decreases as more network nodes share one process b) Increases as each node runs the process faster c) Can only change by adding a wavelength node
Planck's constant. Defines both: a) The minimum unit of energy, and b) The minimum length of space c) For some unknown reason	*Network density.* Defines both: a) The basic processing action is a *transverse circle*, and b) The basic unit of length is a *planar circle* c) Both circles are the same size by network symmetry,
Quantum waves. In theory, a photon quantum wave: a) Spreads outwards as a sphere b) Passes through two slits to interfere with itself c) Can collapse to any point regardless of its spread d) Becomes a physical event with a probability that depends on the net power of the wave at each point	*Processing waves*. A photon processing wave: a) Transmits instances outwards on the surface of space b) Instances pass through two slits and interfere on exit c) Can restart at any node regardless of its spread d) The physical event probability depends on server access defined by the net quantum wave power at each point
The law of least action. Light always takes the path of least action to a detector, for some unknown reason	*The law of all action.* Light takes every path to a detector and the first to arrive restarts the photon process
Retrospective action. A photon decides the path it took to a detector after it arrives, which is backwards causality	*Just in time action.* Photon instances take every path and the one it re-spawns from defines the photon's "path"
Non-physical detection. One can detect an obstacle on a path not physically taken, which is physically impossible	*Quantum detection.* Blocking an alternate path prevents quantum interference and alters the physical results
Quantum spin. A photon polarized in one plane spins: a) With the same spin for any axis, for some reason b) Into other planes, according to angle	*Quantum spin.* Quantum processing in four dimensions a) Restarts give the total spin for any axis b) Projects onto other planes according to angle as it spins
Superposition. Quantum waves superpose in combinations that can't physically exist	*Processing overlays.* Quantum processing can overlay in all possible ways as long as there is no overload
Entanglement. The random spin of an entangled photon instantly defines the other's spin anywhere in the universe	*Merging.* Entangled photons merge their processing, so two servers run both photons until the next restart
Holographic principle. All the information about a point of space receives can be encoded on a surface around it	*Transmission principle.* All the information a node receives is transmitted by its sphere of neighbors
Quantum paradox. Unreal quantum waves generate real physical events	*Quantum reality.* Real quantum waves generate virtual physical events

DISCUSSION QUESTIONS

The following questions are addressed in this chapter. They are better discussed in a group to allow a variety of opinions to emerge. The relevant section link is given after each question:

1. What is the mystery of light? (3.1.1)
2. According to current physics, is light made of waves, particles or both? (3.1.2)
3. In Young's experiment, does a photon go through both slits or just one? Give reasons. (3.1.3)
4. Bohr's Copenhagen view lets the quantum world exist for calculations but nothing else. What is the problem with this? (3.1.4)
5. Can counterfactual events that didn't happen define physical outcomes? Give reasons (3.1.5)
6. What proves for sure that light is a wave? (3.2.1)
7. What does it mean to say that we are three-dimensional "Flatlanders"? (3.2.2)
8. Can light waves vibrate in a physical direction? If not, in what direction then? (3.2.2)
9. Why hasn't light slowed down, even after traveling for billions of years in space? (3.2.3)
10. If light is a wave that travels in empty space, what mediates it? (3.2.3)
11. Why can nothing ever travel faster than light? (3.2.4)
12. What does every photon in the electromagnetic spectrum have in common? (3.3.1)
13. What is energy in processing terms? (3.3.2)
14. Why does all energy come in Planck units? (3.3.3)
15. If a quantum wave is a processing wave, how does it spread? (3.4.2)
16. Why is it wrong to say that a photon "has" a quantum wave? (3.4.3)
17. Will hidden variables ever explain why photons hit a screen at random points? (3.5.1)
18. Is a photon a wave, a particle, or both? If both, how can that be? (3.5.2)
19. How can a quantum wave collapse instantly to a point, regardless of its spatial extent? (3.5.2)
20. Why does a photon wave always deliver all its energy instantly at a point? (3.5.2)
21. How can a photon go through both Young's slits but still hit the screen at a point? (3.5.3)
22. Why does a photon's *probability of existence* at a point depend on its quantum wave *power* at that point? (3.5.3)
23. What causes quantum randomness? (3.5.3)
24. Why can't physics explain how light always finds the shortest path? (3.6.2)
25. How does a photon always find the shortest path to any destination? (3.6.3)
26. Why is a photon's spin on any axis always the same? (3.7.1)
27. Why does a filter that blocks horizontally polarized light not block vertically polarized light? (3.7.2)
28. How can a photon of polarized light pass *entirely* though a filter that blocks most of it? (3.7.3)
29. How can physically incompatible quantum states occur at the same time, i.e. superpose? (3.8.1)
30. Can Schrödinger's cat be both alive and dead? Explain. (3.8.2)
31. According to quantum theory, observation creates physical reality, so is life just a dream? (3.8.2)
32. Does the delayed choice two-slit experiment prove that time can flow backwards? (3.8.3)
33. How can a photon choose the physical path it took to reach a detector *after* it arrives? (3.8.3)
34. Can a photon of light detect an object on a path it didn't travel? Is this physically possible? (3.8.4)
35. How do entangled photons *instantly* affect each other faster than the speed of light? (3.8.5)
36. How is the physical world like a hologram? Why does quantum realism require this to be so (3.8.6)
37. If there no evidence for the multiverse, why do so many physicists accept it? (3.9.1)
38. What is the long-sought boundary between the quantum world and the physical world? (3.9.2)
39. What is the quantum paradox? How has physics handled it? (3.9.3)
40. How does quantum realism resolve the quantum paradox? (3.9.4)

41. If quantum entities exist mostly in an unmeasured state, what makes this state "unreal"? (3.9.5)
42. Does quantum theory describe unreality or reality? Give reasons. (3.9.6)

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REFERENCES

Abbott, E. (1884). Flatland: a romance of many dimensions. Retrieved February 22, 2010, from http://www.gutenberg.org/etext/201

Adams, D. (1995). *The Restaurant at the End of the Universe*. New York: Ballentine.

Aspect, A., Grangier, P., & Roger, G. (1982). Experimental Realization of Einstein-Podolsky-Rosen-Bohm Gedankenexperiment: A New Violation of Bell's Inequalities. *Physical Review Letters*, *49*(2), 91–94.

Audretsch, J. (2004). *Entangled World: The fascination of quantum information and computation*. Verlag: Wiley.

Baggot, J. (2013). *Farewell to Reality: How fairytale physics betrays the search for scientific truth*. London: Constable.

Barbour, J. (1999). *The End of Time: The next revolution in physics*. Oxford: Oxford University Press.

Barrow, J. D. (2007). *New theories of everything*. Oxford: Oxford University Press.

Bekenstein, J. D. (2003). Information in the Holographic Universe. *Scientific American*, *289*(2), 58–65.

Bojowald, M. (2008). Follow the Bouncing Universe. *Scientific American*, *October*, 28–33.

Bolles, E. B. (1999). *Galileo's Commandment: 2,500 years of great science writing*. New York: W. H. Freeman.

Cho, A. (2000). Physicists Unveil Schrodinger's SQUID. *Science*, *287*(31 March).

Davies, P., & Brown, J. R. (1999). *The Ghost in the Atom*. Cambridge: Cambridge University Press.

D'Espagnat, B. (1979). The quantum theory and reality. *Scientific American*, *241*(5), 158–182.

Deutsch, D. (1997). *The Fabric of Reality*. Penguin Press: Allen lane.

Einstein, A., Podolsky, P., & Rosen, N. (1935). Can quantum-mechanical description of physical reality be considered complete? *Phys. Rev.*, *47*, 777–780.

Feynman, R. P., Leighton, R. B., & Sands, M. (1977). *The Feynman Lectures on Physics*. Reading, Ma.: Addison-Wesley.

Greene, B. (2004). *The Fabric of the Cosmos*. New York: Vintage Books.

Herbert, N. (1985). Quantum Reality: Beyond the New Physics. New York: Anchor Books.

Kant, I. (2002). Critique of Pure Reason. In M. C. Beardsley (Ed.), *The European Philosophers from Descartes to Nietsche*. New York: The Modern Library.

Kwiat, P. G., Weinfurter, H., Herzog, T., Zeilinger, A., & Kasevich, M. A. (1995). Interaction-free Measurement. *Phys. Rev. Lett.*, *74*, 4763.

Laughlin, R. B. (2005). *A Different Universe: Reinventing physics from the bottom down*. New York: Basic Books.

Lederman, L. M., & Hill, C. T. (2004). *Symmetry and the beautiful universe*. New York: Prometheus Books.

M. Arndt, O. Nairz, J. Voss-Andreae, C. Keller, G. van der Z., & Zeilinger, A. (1999). Wave particle duality of C60 molecules. *Nature*, *401*, 680–682.

Mermin, N. D. (2009). Whats bad about this habit? *Physics Today*, *May*.

Oerter, R. (2006). *The Theory of Almost Everything*. London: Plume, Penguin.

Penrose, R. (1994). *Shadows of the Mind*. Oxford: Oxford University Press.

Salart, D., Baas, A., Branciard, C., Gisin, N., & Zbinden, H. (2008). Testing spooky action at a distance. *Nature*, *454*, 861–864.

Satinover, J. (2001). *The Quantum Brain*. New York: John Wiley and Sons, Inc.

Schiller, C. (2009). Motion Mountain: The Free Physics Textbook.

Tegmark, M., & Wheeler, J. A. (2001). 100 Years of the Quantum. *Scientific American*, (Feb), p68-75.

Walker, E. H. (2000). *The Physics of Consciousness*. New York: Perseus Publishing.

Wheeler, J. A. (1983). Law without law. In J. A. Wheeler & W. H. Zurek (Eds.), *Quantum Theory and Measurement* (pp. 182–213). Princeton: Princeton University Press.

Wilczek, F. (2008). *The Lightness of Being: Mass, Ether and the Unification of forces*. New York: Basic Books.

Wootters, W., & Zurek, W. (1982). A Single Quantum Cannot Be Cloned. *Nature*, *299*, 802–803.

Zeh, H. D. (2004). The Wave Function: It or Bit? In J. D. Barrow, P. C. W. Davies, & J. Charles L. Harper (Eds.), *Science and Ultimate Reality: Quantum Theory, Cosmology and Complexity* (p. http://arxiv.org/abs/quant-ph/0204088). Cambridge: Cambridge University Press.