QUANTUM REALISM

Chapter 3. The Light of Existence[1]

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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)

3.1. INTRODUCTION

The last chapter suggested that light was the first physical thing, a step beyond the outward nothing of space but not yet the static something of matter. This chapter deduces the properties of light from a processing model, including its ability to be a wave or a particle, to detect objects it didn't physically touch, to take all paths to a destination, to choose a path after it arrives and to spin in two ways at once. The premise is only that a photon is a *program* spreading on a processing grid that is the:

"*… primary world-stuff*" (Wilczek, 2008) p74.

The quantum grid isn't what we see, but what outputs what we see, with time, space, mass, charge and energy all outputs. It doesn't exist in space nor does it operate in time: its architecture defines space and its cycles define time (Chapter 2). If relativity describes the space-time operating system then quantum theory describes the "apps" that run on a network whose *nodes* some call the "atoms of space" (Bojowald, 2008). From this perspective, we now consider why light:

1. *Never slows or weakens.* Why doesn't light fade, even after billions of years?
2. *Has a constant speed.* Why is the speed of light a constant?
3. *Comes in packets.* Why does light come in minimum energy quanta?
4. *Moves like a wave but arrives as a particle.* How can light be both a wave and a particle?
5. *Always takes the fastest path.* How can photons know *in advance* the fastest route?
6. *Chooses a path after it arrives.* Is this backwards causation?
7. *Can "detect" objects it never physically touches.* How can non-physical knowing occur?
8. *Entirely passes a filter at a polarization angle*? How does *all* the photon get through?
9. *Spins on many axes, and in both ways, at once.* How do photons "spin"?

Quantum realism derives all these properties from a photon as a program running on a network.

3.2. THE PHOTON PROGRAM

3.2.1. Particle or wave?

In the seventeenth century, Huygens noticed that light beams at right angles pass right through each other, so they must be waves, as if they were objects like arrows they would collide. He conceived of light as an expanding wave front, with each strike point the center of a new little wavelet, traveling outwards in all directions. As the wavelets spread, he argued, they interfere, as the trough of one wave

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[1] Version 2 is the same ideas simplified. Latest versions at: Chapter1, Chapter2, Chapter3 and Chapter4.

cancels the crest of another. The end result is a forward moving envelope that at a distance from the

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

source acts like a ray of light (Figure 3.1a). Huygen's principle, that each *wave front point is a new wavelet source expanding in all directions,* explained reflection, refraction and diffraction. In contrast, Newton's idea of bullet-like corpuscles traveling in straight lines explained only reflection and refraction (Figure 3.1b), but his simpler view carried the day.
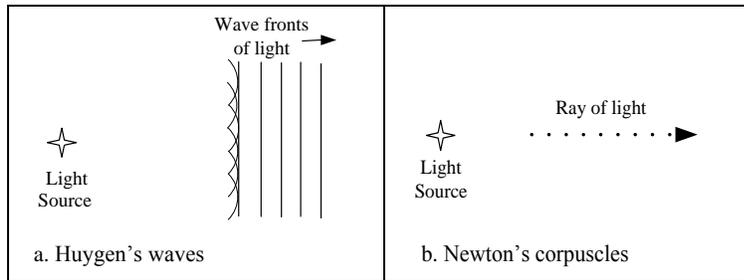
Two hundred years later Maxwell deduced that light is a wave with a frequency and wavelength, but then Einstein argued equally convincingly from the photo-electric effect that it comes in particle-like packets. The theory of light has swung from Huygen's waves, to Newton's corpuscles, to Maxwell's waves, to Planck packets. Today, physics *pretends* that light is a wave *and* a particle, although that is impossible. Three centuries after Newton, the question "*What is light?*" is as controversial as ever. As Einstein commented to a friend 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

Figure 3.2. The electro-magnetic spectrum
(from http://www.antonine-education.co.uk/)

Even now, physics is quite unable to say what light actually *is*.

3.2.2. What *is* light?

In current physics, light is a vibration in an electro-magnetic field that sets positive and negative *imaginary* potentials at right angles to its polarization. This wave oscillating slowly is radio and television, faster is heat and visible light and very fast is x-rays and nuclear rays (Figure 3.2). The light we see is the part of the spectrum that vibrates about a million-billion times a second, with gamma rays a billion times faster while radio waves vibrate a few times a second. For simplicity, from now on "light" will refer to *any electro-magnetic vibration*. Modern lasers can produce a *pulse* of light at one frequency in one polarization plane, i.e. one *photon.* In contrast a *ray* of light can be many photons polarized on different planes on the same axis of movement.
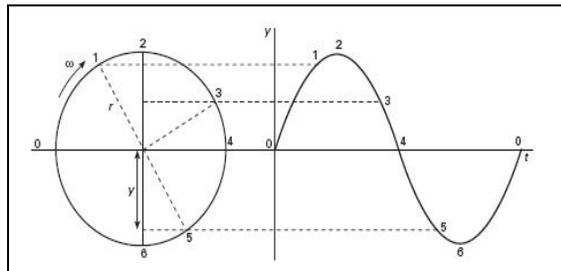

Figure 3.3. A circle maps to a sine wave

We know that light is a wave because separately visible but out-of-phase photons can interfere to give darkness. A non-polarized flashlight beam can't do this but lasers can create polarized light that is individually visible but in combination gives absolute darkness. This *light+light = darkness* is only possible for waves.

Light vibrates as a sine wave that in mathematics maps to a circle extended (Figure 3.3). If a pointer turning like a clock hand in a circle moves on a surface the amplitude result is a sine wave (Figure 3.4).
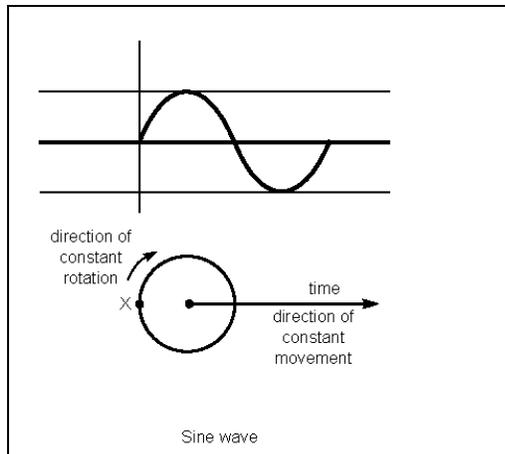
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Figure 3.4. A sine wave is a moving rotation

The same equations describe a water wave as an oscillation between the forces of gravity and elasticity acting at right angles to its surface. When a wave arrives, it pushes a surface water molecule say up, then gravity pulls it back down, then the water elasticity pushes it back up, etc. (Figure 3.5). The wave just moves water molecules up and down, hence a cork just bobs up and down as a wave passes. What "travels" on the surface is a *transverse oscillation* not the water itself. If light travels the same way, space must be a surface that can oscillate transversely.

3.2.3. What mediates light?

If waves vibrate a medium, and light is a wave, then it must have a medium. *Something must move to create light,* but with no physical ether physics simply declares that:

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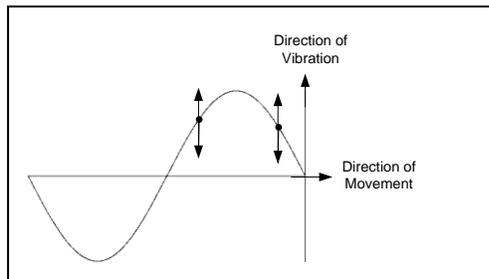

Figure 3.5. Waves alter a surface

In this view, light waves oscillate an electro-magnetic field, whose electric changes are said to cause the magnetic changes that cause the electric changes and so on, in a:

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

This 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. Does current physics see light as an electro-magnetic Ponzi scheme?

Ancient light, such as cosmic background radiation, has traveled the universe for billions of years to reach us but still arrives at the speed of light. It is colder because the expansion of space has increased its wavelength, but its speed and amplitude are unchanged. If light travels without slowing or diminishing, it has found the secret of perpetual motion!

Every physical wave involves friction by the inevitable moving of matter up and down, so it must eventually diminish by the second law of thermodynamics, with no exceptions[2]. Light as a *frictionless wave of nothing* is like no wave that we know, and a century of physics hasn't answered the question:

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

In quantum realism, programs run forever because the grid always runs. A physical wave fades by friction but a processing wave spreads on a network that always processes anyway. Empty space as a null processing network is no more empty than an idle computer is idle[3], hence the:

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

A photon as a program transmitted by an ever-active grid will never fade.

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[2] Planets orbit forever, but the gravity that maintains this derives from the same grid source as light.

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

3.2.4. The refresh rate of space

Einstein deduced the speed of light from how the world behaves, but *why* must it be so[4]? The current view of physics, 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

That it is because it is has never been a very satisfactory answer in science. In quantum realism, the speed of light is the network refresh rate, which is finite because every processor runs at a finite rate, e.g. a 5GHz computer runs at 5,000,000,000 cycles per second. If light goes from one node to the next each cycle, its speed will be the speed of the network, i.e. its cycle rate. If the speed of light is a property of the space that transmits it, it should be called the *speed of space*[5].

The speed of light in a vacuum is a constant, so why does it go slower in water? When light moves in water we *say* the medium is water, and when it moves in glass we *say* the medium is glass, but when it moves in empty space, what then? Is it a wave of nothing? In quantum realism, whether light travels in glass, water or empty space, the medium is always the grid. In glass or water, the grid must process that matter as well as the light, so it goes slower, as a computer game's frame-rate drops if it is busy with other things.

The grid as a network with a base cycle rate also keeps photons in 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, say near a massive star, the photons go slower *but still keep the same order,* e.g. in gravity lensing, photons from a cosmic event arrive on earth at different times by different paths, but are still in lock-step order for each path. This maintains causality, as if one photon could overtake another one could see an object arrive before it left! Temporal causality requires photons to stay in sequence and the grid's cycles rigorously maintain this.

Why matter needs energy to *start* moving but light needs energy to *stop* it is covered in Chapter 5.

3.2.5. Space as a surface

Does light oscillate in a physical direction, as sound does? To a physical realist, the answer seems obvious, as how else could it vibrate? Sound is a *longitudinal wave* that expands and contracts air molecules in its travel direction, so there is no sound in empty space. In contrast, light is a *transverse wave,* that oscillates at right angles to its line of travel, and it transmits in the vacuum of space or we couldn't see the stars at night. Yet this transverse vibration can't be in a physical direction since space is *isotropic,* i.e. "up" from one view is "down" from another. A spatial direction can't give the positive-negative charges of electro-magnetism because no spatial direction is absolute.

In quantum realism, light moves on space as water waves do on a lake, except the surface of space has three dimensions not two. As Chapter 2 explained, space as a hyper-sphere surface can have dimples and dents just as a sphere can. So a photon is a transverse harmonic oscillation moving on the surface of space, as complex number theory[6] says it is. To *us* light rotates in an *unreal* space, but who made us the arbiter of reality?

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[4] Saying a photon 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 makes the speed of light a maximum for our universe?

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

[6] In normal multiplication, a number times two doubles it, and times 4 adds it four times, e.g. 5 x 2 = 10, and 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, so 5 x *4i* = 5.
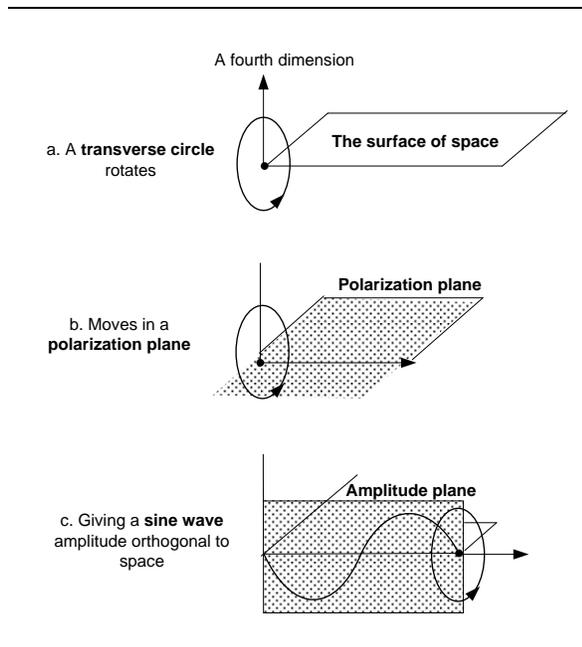
Figure 3.6. A transverse circle moving on space

In Abbot's story, Flatlanders who lived on a two dimensional surface could only see a sphere of three dimensions as a set of expanding and contracting circles passing through their plane (Abbott, 1884). A circular rotation moving on their plane would appear as a sine wave in an imaginary (to them) dimension, just as electro-magnetism appears to us. So are we *three dimensional Flatlanders?* A transverse rotation *on* space (Figure 3.6a), moving *in* space (Figure 3.6b), will create a sine wave in a dimension outside space (Figure 3.6c). So perhaps complex numbers explain electro-magnetism because it really does turn into a dimension outside our space (Figure 3.7):

"*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

We can't enter the complex plane because we are made of quantum waves that can never leave the surface upon which they vibrate.

3.2.6. Fields and dimensions

Currently, light is seen as vibrating electrical and magnetic fields, where according to Feynman:

"*A real field is a mathematical function we use for avoiding the idea of action at a distance.*" (Feynman, Leighton, & Sands, 1977) Vol. II, p15-7
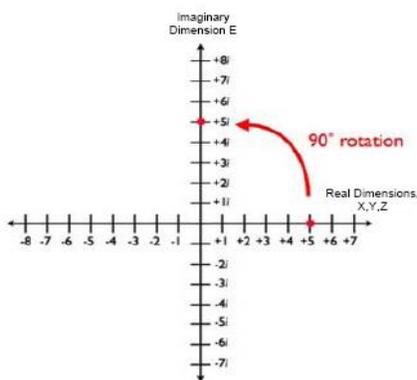

Figure 3.7. Complex rotations

Fields are today so common in physics that we forget they are explanatory concepts not observed reality. We don't see gravity, only its effects, e.g. the earth holds the moon in orbit by its gravity, which is a field that creates a force at every point in space. Likewise, an electric field sets values at every point, even if zero, and so on for other fields. A field that adds a value to every point of space in effect *adds a degree of freedom* to it, i.e. a new dimension. Adding many dimensions creates an interaction problem as string theory's 10^{500} possible architectures testify. As fewer dimensions is better so field unification is a primary goal of physics today, i.e. reducing all the fields of physics to one.

Quantum realism uses just one *quantum dimension,* whose values define the *quantum field* behind everything. Feynman called it the *vector potential*, Born called it the *probability amplitude,* and Hiley called it the *quantum potential* (Davies & Brown, 1999) p138, but physics today calls it Ψ, the *quantum function,* and Chapter 4 describes how this one "field" rules all the others.

3.2.7. The Planck program

In a virtual world, a *processor* runs a *program* to set the *pixel* values an observer sees. In quantum realism, nodes process quantum state pixels as photon programs spread on a grid network by the equations of quantum theory. As explained later, these pixels are only "observed" when two programs overload a grid node, causing it to reboot and restart them both, in a *physical event*.
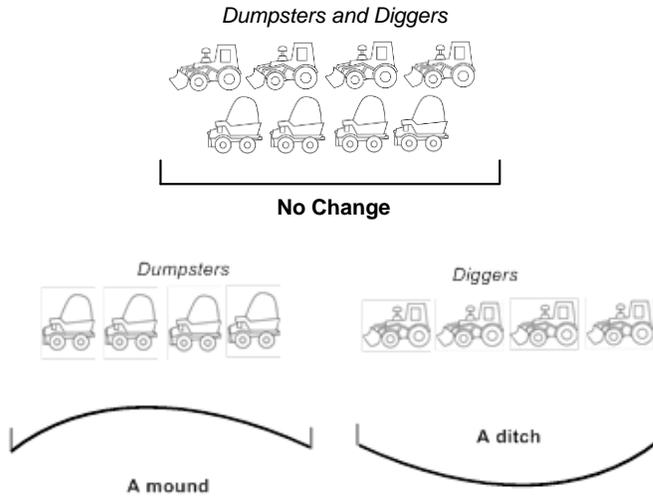
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Dumpsters and Diggers

No Change

Figure 3.8. Processing distributed

The set of computing operations a processor can do is its *command set*, e.g. "add one" is a command set operation. Adding new operations for databases and networks gave *complex instruction set computing* (CISC), until it was found that reduced instruction set computing (RISC) is better. The grid's proposed command set is the ultimate RISC design, of one operation:

> *Set the next value in a transverse circle*

Adding one in a circle always works as a circle's end is also its start. If space is a surface, a circle transverse to it allows the absolute values of electro-magnetism. If a *Planck program* is the instruction set needed for a transverse circle, it is now suggested that one Planck program distributed over the grid can generate the entire electro-magnetic spectrum.

Distributing processing among processors improves performance, so some of the world's fastest supercomputers are mainly banks of video cards. Likewise, distributing a Planck program more or less is an efficient use of processing. To understand this, imagine an equal number of digger and dumpster trucks, where each adds or removes the same amount of dirt in a day (Figure 3.8). If they all work at the same spot, after a day the result is no change as the same amount is a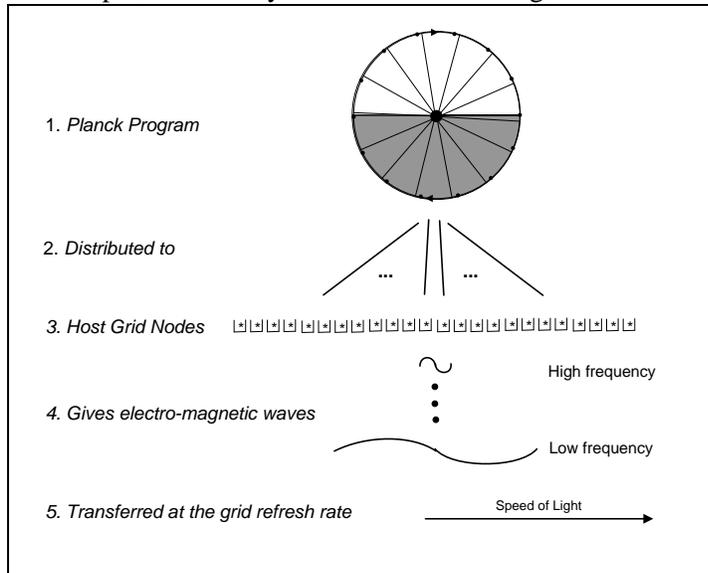dded as is taken away. But if the team divides, with diggers at one spot and dumpsters at the next, the result is a mound and a hole. If the diggers and dumpsters move on each night, the result is an up/down pattern moving on the surface, i.e. a wave[7].

1. *Planck Program*

2. *Distributed to*

3. *Host Grid Nodes*

4. *Gives electro-magnetic waves* — High frequency / Low frequency

5. *Transferred at the grid refresh rate* — Speed of Light

Figure 3.9. Light is a Planck program spread out

Likewise a Planck program setting a circle of values in one node each cycle gives "nothing", or empty space, but the same processing spread over two nodes gives an up-then-down effect which passed on is a wave. A Planck program spread over more nodes gives the sine waves of the electro-magnetic spectrum (Figure 3.9). As the Planck program is passed on, a new node begins just as another finishes, so whatever the spread the total processing doesn't change.

The same program that in one node is space is in many nodes light, so photons are just what we call space spread out, hence a photon has no rest mass because if it rested for its wave train to catch up, it would revert back to empty space.

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[7] In this analogy, the landscape also resets - say scavengers fill the hole and demolish the mound each night.

3.2.8. Energy as a processing transfer rate

Energy is a concept useful in physics because it works but what is it? It manifests in kinetic, heat, radiant, chemical, nuclear, electric, magnetic and potential forms, and by Einstein, also mass, but what energy actually consists of is never stated.

The energy of light varies by its frequency squared, so a *black body* that emits light equally at all frequencies should increase its higher frequencies equally as its temperature increases. The nineteenth century *ultra-violet catastrophe* was that raising the temperature of black body, like a furnace, in theory give a fatal dose of x-rays but in practice, it didn't. Planck solved the problem by making atoms emit energy in multiples of a basic quantum[8] so the higher frequencies are harder to get. This predicted black body radiation correctly, then Einstein quantized light itself by the photo-electric effect, which was unexpected, and why it is so remains a mystery to this day. Why does energy come in lumps?

In this model, energy is the processing *transfer rate at the node*. A high frequency photon with a short wavelength has less nodes to run the same Planck program, so each processes more per cycle, i.e. has more energy. A long wavelength photon with more nodes to run the same program allocates less processing to each node, and so has less energy.

A photon's energy is its frequency *multiplied by* Planck's constant (a tiny per second energy). If Planck's constant represents the Planck program of each photon, the amount of processing transferred per node, or energy, is that program *divided* over the nodes in its wavelength. If one adjusts for the different units by the speed of light, a photon's energy is indeed Planck's constant divided by its wavelength[9].

We see Planck's constant as the *minimum* per second energy transfer, but at the quantum level it is the *maximum* per cycle processing transfer. Planck's constant represents the basic program of the grid, so it is both the smallest physical event, because a quantum entity can only change in Planck program units, and the biggest quantum change because the grid channel bandwidth is one Planck program.

A photon's energy then comes in discrete packets because its wavelength must change one node at a time. One less node running the same program changes the per-node processing, or energy, in fixed amounts. Light energy is quantized because the grid is digital.

Equally higher frequencies are harder to come by, as Planck concluded, because removing one node from a shorter wavelength changes the energy more. The highest wavelength, of two Planck lengths, must double its energy to reach the next frequency, which is that of empty space! In this view, the universe began with *extreme photons* - Planck programs spread over two nodes - then the expansion of space created the rest of the electro-magnetic spectrum, from radio-waves to gamma rays. In the next chapter, matter evolved from extreme light.

3.2.9. The photon package

A photon hitting a photographic plate creates a dot, but a wave arriving should be a smear. Radio waves are many meters long, so they should take time to arrive, even at light speed, but they don't. If they did, in the delay between a photon wave's first hit and the rest of it arriving, the tail could also hit something, so a photon could hit in two places at once, which it never does! The question is:

"*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

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[8] The word quantum just means "a discrete amount". In quantum theory, this amount is Planck's constant.

[9] The Planck relation $E = h.f$ describes a photons energy, for energy E, frequency f, and Planck's constant h. For a wave of wavelength λ travelling at speed c, frequency $f = c/\lambda$. So $E = h.c/\lambda$, i.e. Planck's constant divided by the wavelength, adjusted by a speed of light, which constant reflects the grid refresh rate of 10^{43} cycles per second.

A quantum wave delivers *all* its energy *instantly* at a point, but a physical wave must "gather" its energy over its wavelength. Only a program has nothing to gather, as each node running the program can instantly restart it *entirely,* so quantum collapse is an all or nothing processing restart (see 3.3.5).

3.2.10. The granularity of the grid

Plank's constant defines the size of space because if it were smaller, atoms would be smaller and if it were larger quantum effects would be more evident. Yet why should the basic unit of energy also define the size of space? There seems no reason for the two to connect.

In this chapter a photon's energy is its processing rate at the node and Planck's constant represents a Planck program, *transverse circle* of values, whose size defines this basic unit of energy.

In the last chapter, a photon's movement was set by a node's *planar circle* of neighbors that by Pythagoras's theorem define the "distance" between nodes, and the planar circle size again defines this.

If *the grid is symmetric*, transverse and planar circles are the same size, so Planck's constant, the energy of a transverse circle, also defines the planar circle that sets the size of space. Planck's constant links space and energy because it is the *granularity of the grid* that creates both.
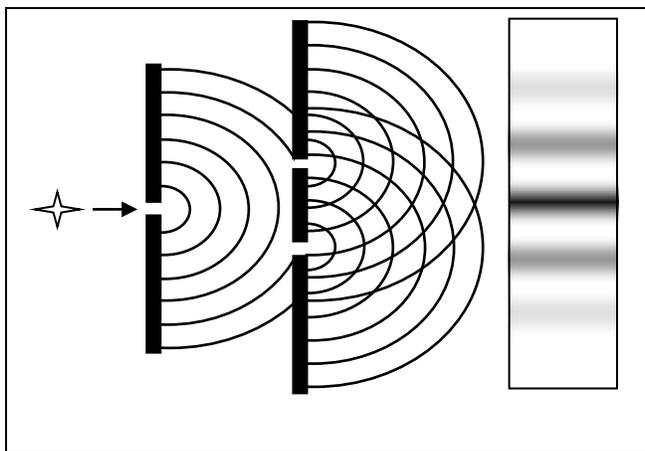

Figure 3.10. Young's double slit experiment

3.3. IMPLICATIONS

3.3.1. Young's experiment

Over two hundred years ago Young did an experiment that still baffles physicists today - he shone light through two slits to get an interference pattern on a screen (Figure 3.10). Only waves diffract like this so a photon must be a wave, but why then does it hit at a point? Or if photons are particles how do they interfere like waves? To find out, physicists sent *one photon at a time* through Young's slits. Each photon gave the expected dot, then the dots formed an interference pattern whose most likely impact was *behind* the slit barrier! The effect was independent of time, so shooting one photon through the slits each year gives the same pattern. Each photon can't know where the previous one hit, so how does the pattern emerge?
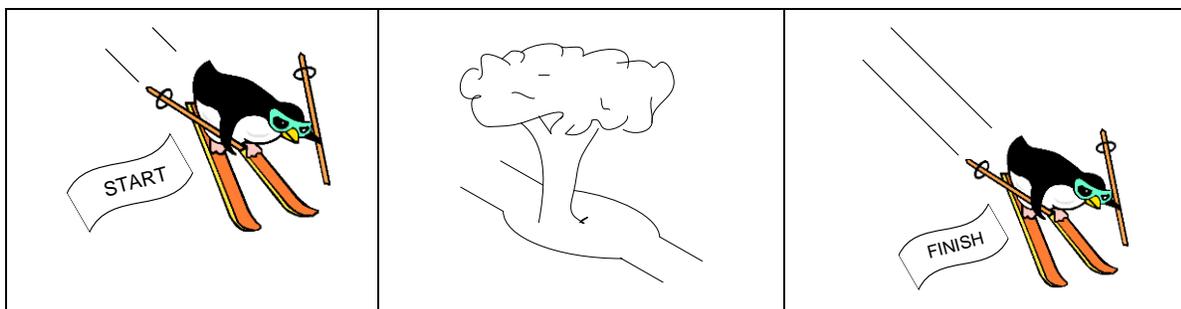
***a.** A particle starts*	***b.** A wave flows*	***c.** A particle finishes*

Figure 3.11. Wave-particle duality

In an objective world, one could just see the slit a photon went through before it hit, but our world's operating system doesn't permit this. Detectors placed in the slits to see where the photon goes

just fire half the time. A photon *always* goes by one slit or another, *never* through both at once. In this conspiracy of silence a photon is a particle when we look but a wave when we don't, like a skier sliding by both sides of a tree but still crossing the finish line intact (Figure 3.11). The problem is:

1. *If a photon is a wave*, why doesn't it smear over the detector screen, as a wave would?

2. *If a photon is a particle,* how can it give an interference pattern?

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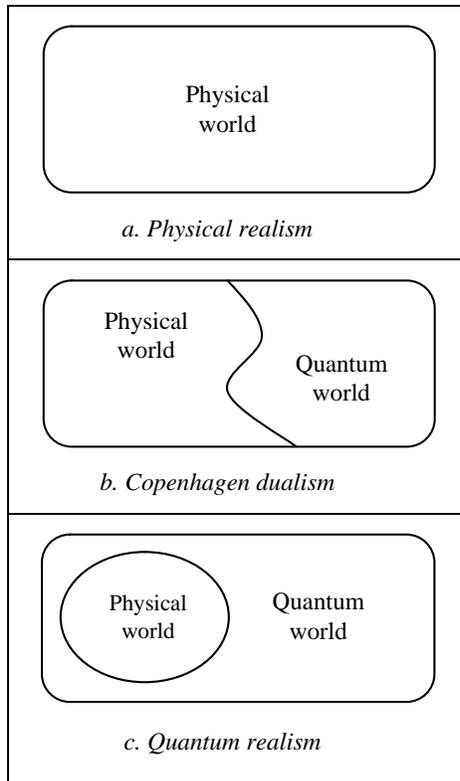
3.3.2. The Copenhagen compromise

Figure 3.12. a. Physical monism, b. Bohr's dualism, c. Quantum monism

After centuries of dispute over whether light is a wave or a particle, Bohr devised the *wave-particle* compromise that holds today. He put the idea in Copenhagen 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.

This *don't ask, don't tell* policy lets a photon be a wave, as long as it becomes a particle when we look. This is convenient, as now physicists can use the formula that fits, yet a particle can never be a wave nor a wave a particle. In no physical pond do rippling waves suddenly become point particles when seen, nonetheless Bohr successfully sold the *big lie*[10], that light is a *wavicle*, as Gell-Mann noted in his 1976 Nobel Prize speech:

"*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, like the mind-body dualism of Descartes, is a mystical marriage of convenience between incompatible domains, accepted by those who want to believe.

Quantum theory and relativity deny the norm of physical realism (Figure 3.12a) so Bohr's compromise was to let the quantum world co-existed as an equal with the classical world (Figure 3.12b) (Audretsch, 2004) p14. In private, he denied the quantum world but in public he had to accept it in order to get on with using its equations.

Quantum realism as a *non-dual monism* then takes the next step of making classical mechanics a subset of quantum mechanics (Figure 3.12c), given that physical events are a subset of quantum events.

3.3.3. How come the quantum?

As Feynman famously said:

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[10] A big lie is a statement so outrageous that people think it must be right or it wouldn't be said. A big lie of last century was the myth of a master race and this century we have the myth of equality. In quantum realism, free choice gives a world that can't be controlled by any master and being different is how life evolves.

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

Quantum theory explains the two-slit 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 thing 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 according to the interference strength. The mathematics doesn't say what this wave is that goes through both slits, nor why it suddenly shrinks to a point when observed, prompting Wheeler's question: *How come the quantum*?

To see how strange this is, suppose the first photon in a two slit experiment hits a screen at some point to become the first dot of what is *always* an interference pattern. Now suppose the first photon of another experiment, with a detector blocking the other slit, 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 from the same source 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. If the photon could have gone through the other slit, there is interference, but if it couldn't, there isn't. How can a *counterfactual event* that could have happened but physically didn't, change a physical outcome?

This unlikely tale of imaginary waves that collapse when viewed makes no sense, yet it is the most fertile theory in the history of science. Nonetheless, it 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 perfectly predict physical events don't exist is unsatisfactory.

2. *What is quantum collapse?* Why must the wave collapse if viewed? The current answer that quantum waves collapse "because they do" is equally unsatisfactory.

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

3.3.4. What are quantum waves?

By the [no-cloning theorem](#) (Wootters & Zurek, 1982), *we* can't copy quantum states because reading quantum data requires a physical event that alters it, but *the system* that made them in the first

place can copy them any time it wants. Information is easy to copy, so it comes as no surprise that nature is the ultimate copy machine.
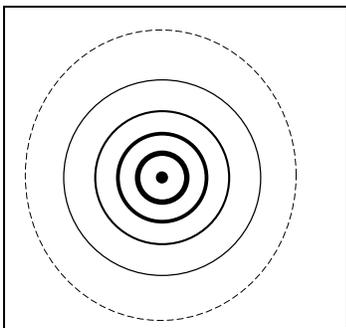
The processing field

In quantum realism, any program put on the grid immediately spreads out in all directions, like ripples on a pool (Figure 3.13), but in three dimensions not two. That each node passes it's processing on to its neighbors each cycle supports *[Huygens principle](#)* that light is a wave spreading with each point a new wave source. The network passes on the processing at one node per cycle, i.e. the speed of light.

Figure 3.13. Pond ripples

As Gauss noted, a pebble dropped in a pool spreads its initial energy out in ripples so that the *energy flux* per ripple is constant but for friction. A program spreading instances on a grid network will follow the same law but with no friction and in three dimensions. The program, or *processing flux,* is constant but as it distributes on a sphere surface its power will reduce as an inverse square of distance, as electrical, magnetic and gravitational fields do. In addition, processing can cancel at the node as fields do at a point[11] and if passed on every cycle will

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

propagate at the speed of light, again as fields do. The next chapter attributes all the fields of the standard model to different processing effects.

Processing shared runs slower not less

Yet while wave ripple reduces in amplitude as it spreads, processing that spreads just slows down, e.g. if a Planck program is shared between two nodes, in one cycle one node gets the up instructions and the other down, and the next cycle it is reversed. Think of two men sharing a shovel, where in the time one man can dig one hole with one shovel, two men with one shovel can only dig half a hole each. One program distributed over two nodes runs half as fast on each, and in general a *program distributed runs slower not less at each node.* As a quantum wave spreads, the frequency reduces not the amplitude.

A photon program "exists" in processing terms by allocating its code to the grid, regardless of the distribution. Whether an electron quantum wave is spread over a galaxy or collapsed in a particle reboot at a node point doesn't matter. For a program, where it runs is irrelevant, as long as it does.

For a program on a network, any copy of it running however slowly is an *instance.* [Instantiation](#) is an [object orientated design](#) method that lets screen objects like buttons inherit code from a single source class[12]. A photon as a program can run *instances* of itself along its wavelength that once started must eventually complete, however slowly. A photon can spread on the grid as a cloud of instances all sharing one Planck program.

Processing can restart anytime

If a photon is a wave spread out, how can it arrive at a point? To Einstein, as to Newton, a photon was a particle, a physical thing located in space that traversed a fixed path from its initial start state to hit the screen at a point. So when quantum theory said that the path to where it hit was decided *when it arrived,* and was proved right, physical realism had only two options:

"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

Either there was an unknown path a particle travelled before it hit, or quantum collapse had some other physical base. This problem, which Einstein raised and Bohr dismissed, still haunts physics today.

According to 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 quantum waves are physically impossible. Physical reality itself isn't physically plausible so why should quantum theory be so! That one can't "reify" quantum states (make them physical) doesn't mean they don't exist. Quantum waves are plausible as programs, because program instances spreading on a network can take every path to a node point, then "collapse", i.e. restart from one instance, or one state as quantum theory says.

A physical realist might ask, if a photon moves as a wave of instances, which one is *the photon*? The question betrays a bias that a photon is a thing. We see a photon interact in one place and think it moves the same way, but that is just an assumption tacked onto the facts. Quantum theory asserts that photons *travel* as spreading waves that *interact* at a point. Its critics couldn't fault this logic because there is no fault. If every observation is an interaction, we don't know how the photon travels. To say a photon *has* wave function is the stubborn illusion that it is an inherent *thing*. In quantum realism, *the photon is the quantum wave,* and the particle we see is a view created on demand. Classical mechanics describes the physical world stage, and quantum mechanics describes what goes on backstage.

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[12] So all screen buttons instantiating a class look the same because they run the same code.

3.3.5. What is quantum collapse?

Quantum waves collapse into physical particles, but physics cannot say why:

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

To Einstein, quantum collapse was absurd, as it implied faster than light travel. If a photon was a spreading wave, as quantum theory said, before it hit a screen its wave function exists at points A or B with some probability, but after it hits, it is entirely at point A say not at B. The moment A "knows" it is the photon, then B "knows" it isn't, but as the screen moves further away eventually A and B could be in different galaxies. If the collapse is *immediate,* how does nature keep this order? How can two events *anywhere in the universe* be so synchronized?

Quantum theory sees the standard model's particles as three-dimensional waves that spread to any size then collapse to a physical point if observed. This makes no physical sense but a *program* passed on a network can indeed restart at any point node that overloads and *reboots*, to restart the program anew. Processing spreading on a network must eventually overload, giving a node reboot that:

a. *Is irreversible*. A reboot loses all previous information, so it can't be reversed.

b. *Loses nothing*. When a distributed program is restarted in a reboot no processing is lost, as the processing before and after is the same.

c. *Allows change*. When the programs that caused the node overload are restarted in a reboot, processing can be re-allocated in potentially new ways.

A reboot explains how a potentially vast quantum wave can suddenly disappear as if it never was. If quantum collapse is a server restart, every *child* instance must stop for it to happen. So the collapse of the wave function is just the inevitable disbanding of child instances when a parent program restarts. The quantum states that disappear are *program instances not things*.

What *actually* arrives at a detector screen isn't a lonely particle looking for a place to hit, but a cloud of instances requesting processing from nodes busy processing the screen's matter. If a node gets more processing than it can handle, it reboots, i.e. tries to reload *all* its processing. In a client-server case, of a source with many instances, every reboot can't succeed. The first node to access the server to restart the *entire* photon program is where the photon "hits" the screen.

 Critical to this perspective is the recognition that quantum entities are processes not things. If two electrons collide, we see those leaving as the same ones that entered, but they are actually brand new, just off the quantum press, because the information that went in was lost in the reboot. Quantum entities are continuously annihilated and created but the processing is constant. Every physical event is a new creation, and only the conservation of processing maintains the illusion that particles continuously exist.

Why is quantum collapse instant for any distance? How can a quantum wave that is spread over a galaxy instantly collapse to any point in it? The processing answer is that programs don't "go to" a screen pixel to alter it, so likewise a quantum server can alter pixels[13] anywhere on the universe screen directly. The node-to-node transfer limit that we call the speed of light is irrelevant to the server-client link, which can directly change any quantum state at any time.

3.3.6. The quantum lottery

In quantum theory, the power of the quantum wave at any point defines the *probability* a photon will hit there. In quantum realism, the quantum wave is a processing wave and where a photon hits is the node reboot the server recognized. So when many instances overload many nodes, what decides which one successfully reboots?

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[13] Which are quantum states.

Servers are always much faster than clients, e.g. even if a terminal user types as fast as they can, in between each key press the server is servicing hundreds of others. If quantum servers work the same way, the result of a reboot request could be:

1. *Access.* The server restarts the program in that node in a physical event, denying all other nodes access for that cycle, i.e. collapsing the quantum wave.

2. *No access.* The node gets a busy response, so it just forgets that instance and carries on, i.e. this 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 server we have no access to. It is also probabilistic because nodes with more processing from that program have more server access. When many grid nodes reboot, the first one to access the server initiates a program restart that locks out all the others. It wins the prize of *being the photon* for that cycle, and all other instances wither on the grid. A photon never dies because it can be born again from any of its legion of instances.

When a photon wave meets a screen, quantum theory calculates the hit point as follows:

a. Equations describe how the quantum wave evolves.

b. If it reaches the same point by different paths, positive/negative values add for a net result.

c. The net result at each point squared is the *probability it physically exists* there.

Quantum realism explains why this method works as follows:

a. The photon program distributes instances down grid channels as a 3D wave.

b. When instances reach the same node by different paths, positive and negative requests are canceled before accessing the server

c. Client nodes with more processing demands access the server more frequently, and so are more likely to restart the photon program successfully, i.e. host a physical event.

For nodes to cancel positive and negative server requests is an expected efficiency, and that more access makes a reboot more likely to succeed is also expected. The probability that a physical event occurs is the net quantum wave amplitude squared because that is the processing demand that defines

Table 3.1. Quantum mechanics as a network protocol

Quantum theory	*Network protocol*
1. Existence. The probability a photon *exists* is the absolute square of its complex quantum amplitude value at any point in space[14]	*1. Reboot.* The probability a node reboots a program depends on the processing access, which is the absolute processing amplitude squared in a node
2. Interference. If a quantum event can occur in two alternate ways, the positive and negative amplitudes combine, i.e. they interfere[15]	*2. Combination.* If program instances reach a node by alternate grid paths, positive and negative values combine, i.e. they interfere
3. Observation. Observing one path lets the other occur without interference, so the outcome probability is the simple sum of the alternatives, i.e. the interference is lost[16]	*3. Obstruction.* An obstacle on any path obstructs instances traveling that path, letting the alternate path deliver its processing unchanged, i.e. the interference is lost

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

[15] If Q_1 and Q_2 are the probability amplitudes of the two ways 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.

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

server access[17]. The outcome is random *to us* because it involves server choices we have no access to. Table 3.1 presents Feynman's quantum mechanics (Feynman et al., 1977) p37-10 as a network protocol to resolve program packet collisions. It explains Young's experiment as follows:

The photon program distributes instances through both slits that interfere as they exit, even for one photon at a time. They then overload the screen nodes and the first to restart the program is where the photon "hits". Interference from the slits alters the processing demand that alters the probability a node will be accessing the server when it overloads and reboots. If detectors are in both slits, both fire equally, as both nodes have equal server access. If a detector is in one slit, it only fires half the time as the server is busy with instances going through the open slit half the time. This answers questions like:

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

b. *Does it arrive at one screen point?* Yes, the photon program restarts at one node screen point.

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

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

Quantum realism, in a nutshell, is saying that quantum theory is true.
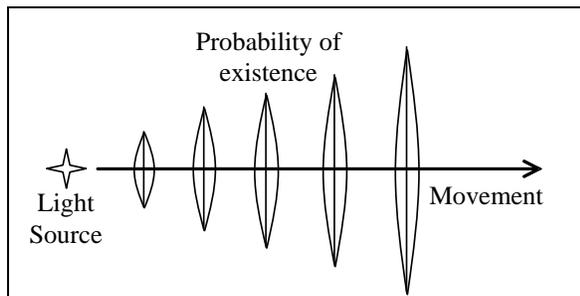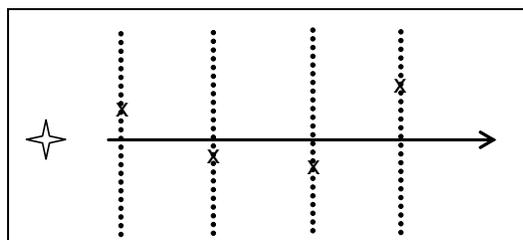
3.4. HOW LIGHT MOVES

A program spreading instances on a network can move as a wave but arrive as a point event, i.e. be both a wave and a particle. That a photon travels as a cloud of instances explains how it behaves.

3.4.1. Light takes every path

If light moves as a wave, it should bend round corners, as sound waves do when we hear people talking in the next room and indeed it does. In 1660 Grimaldi found that light does bend, but by less due to its shorter wavelength. In Figure 3.14 a photon wave varies in power along its line of travel and so is more likely to exist at the thicker sections. Hence when photons are detected by screens at different distances, the hits aren't in a perfect straight line but randomly spread about it (Figure 3.15). A physical photon particle would have to travel in a zigzag path to explain this.

Figure 3.14. A *photon probability of existence*

Figure 3.15. Detection of a "ray" of light

3.4.2. The law of least action

Newton rejected Huygens's wave theory of light because:

"*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

If light only travels in a straight line *on average,* why can't it sometimes "bend into the shadows", to show us a torch beam from the side? Why don't photon waves have a wake, like the turbulence of a high speed bullet? Behind this problem lies a deeper one that has puzzled thinkers for centuries. As

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[17] The power of a sine wave is the square of its amplitude.

Hero of Alexandria noted, light always takes the shortest path, so how does it find that path? It might seem obvious that it is a straight line but how, at each step, does a photon know what *straight* is?[18]
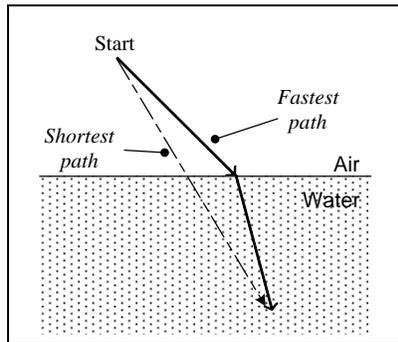

Figure 3.16. Light refracts

In 1662 Fermat amended the law to be the path of least time, as light *refracts* when it enters a transparent medium like water where it travels slower, to take the fastest not the shortest path (Figure 3.16). Imagine the photon as a life guard trying to save a drowning swimmer as quickly as possible. Is the dotted straight line shown the quickest path to the swimmer? If the lifeguard runs faster than he or she swims, it is better to run further down the beach then swim a shorter distance, as shown by the solid line in Figure 3.15. The dotted line is the shortest path but the solid line is the fastest and that is the path light takes. How does light know *in advance* to take this faster path*?* In 1752, Maupertuis suggested that:

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

This *law of least action,* that nature always does the least work, was developed mathematically by Euler, Leibnitz, Lagrange, Hamilton and others, sparking a furious philosophical debate on whether we live in "*the best of all possible worlds*". Despite Voltaire's ridicule, how a photon finds the fastest path remains a mystery today, e.g. light bouncing off the mirror in Figure 3.17 *could* take any of the dotted

Figure 3.17. Principle of least action

paths shown, but by the principles of optics always takes the solid line fastest path. 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:
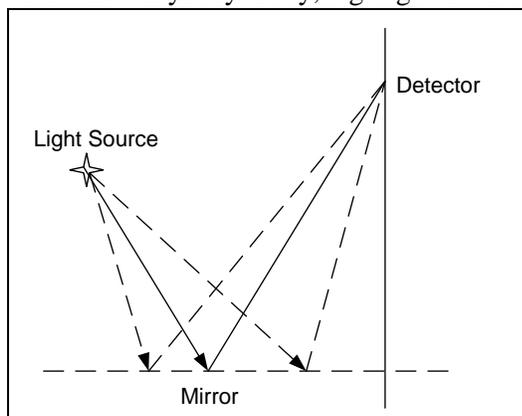
"*Does it 'smell' the neighboring paths to find out if they have more action*?" (Feynman et al., 1977) p19-9

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.

3.4.3. The quantum law of all action

Does the photon calculate the best path to take? Super-computers running a million-million cycles a second currently 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 one particle, but an ensemble of 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 no physical particle can do that. It became, like the rest of quantum theory, another physical impossibility that just happened to work perfectly.

In quantum realism, Feynman's method is what the photon actually does. Photon instances actually take *all available grid paths,* and physical reality is decided down the line by the first restart. The

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

instance that happens to take the fastest path to a detector reincarnates as the photon in a physical event, making its path the path the photon took. The restart makes all other instances disappear, like a clever magician removing the evidence of how a trick is done.

Indeed, how else could a law of least action arise? A photon can't know in advance the best way to an unknown destination *before* it leaves, so it takes them all and *picks the fastest later*. In a virtuality, calculating and taking a path are the same thing, so this is an efficient way.

So a photon doesn't know anything in advance. It lets instances take every path, and the fastest to arrive at a detector becomes it, on a first come first served basis, with quantum collapse the necessary information garbage collection. A photon hitting a screen is not a solitary particle taking one best path, but a quantum ensemble exploring every path, that disbands when the job is done.

Every physical event derives from many quantum events, as the quantum world tries every option and the physical world takes the best and drops the rest. If this isn't the best of all possible worlds, then it isn't for lack of trying. The physical law of least action comes from a *quantum law of all action,* that:

> *Everything that can happen in physical reality does happen in quantum reality*[19].

This law implies an *evolutionary physics* and in the next chapter matter evolves from light.

3.5. QUANTUM SPIN

Light as processing wave in a fourth dimension can also explain quantum spin.
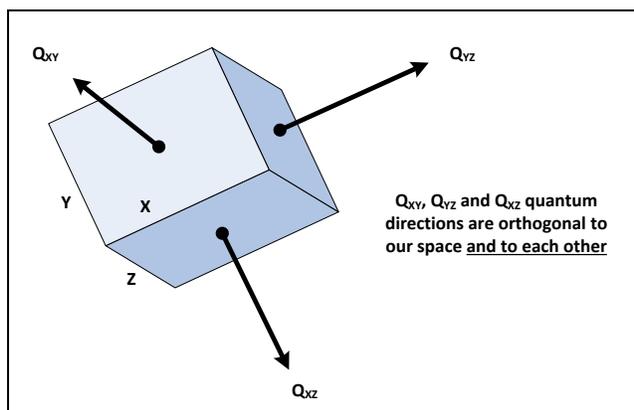
3.5.1. Quantum directions

Figure 3.18. Quantum directions

In current physics, a photon is a complex value turning in an imaginary dimension that doesn't exist. In quantum realism, it is an oscillation *on* space, at right angles to its *polarization plane* into a real fourth dimension.

Note that adding a dimension to the three of our space gives three new *quantum directions* not one[20], all at right angles to each other (Figure 3.18). So light can vibrate in three ways at every point, at right angles to the three planes through it. So a filter that blocks vertically polarized light doesn't block horizontally polarized light, because these oscillations are at right angles *to each other*.

3.5.2. Spin in four dimensions

Spin in four dimensions works like spin in three but with more options. It still has a:

a. *Rotation axis.* Around which the spin occurs, which dimension doesn't change with the spin.

b. *Rotation plane.* In which the spin occurs, whose dimensions swap values as the structure spins.

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[19] Feynman said: "*Whatever is not explicitly forbidden must happen*". Gellman called it the quantum totalitarian principle.

[20] 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 directions.

Imagine a spinning propeller whose blades swap vertical and horizontal extents from the front, but from the side the blade "disappears" as it spins into an unseen horizontal dimension.
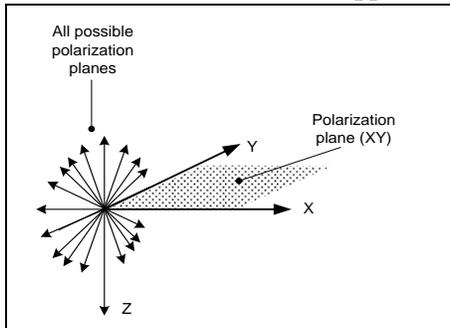

Figure 3.19. Polarization planes

If a photon *spins on its axis of movement,* as a bullet shot from a gun does, it spins into all the planes of its movement axis (Figure 3.19). The direction of its vibration doesn't change because it isn't on the rotation plane[21], so its quantum amplitude projects into every plane of that axis according to angle[22]. When a vertically polarized photon spins into the horizontal plane it disappears entirely, like a piece of paper turned edge that can't be seen at all. The quantum amplitude of a spinning photon appears and disappears like a propeller seen from the side.

A filter at bigger angle to the polarization plane lets fewer photons through but it still lets some through entirely, e.g. only 10% of photons get through a filter at 81° to the polarization plane. How can a photon pass *entirely* through a filter that mostly blocks it? The answer is that a program restart is an all or nothing affair. A quantum server may have many client nodes requesting service, so if a request is not answered the node just drops it. A spinning photon will pass through a filter if by chance its blocked instances don't get server access, leaving the others instances to continue as "the photon".

3.5.3. The curious case of quantum spin

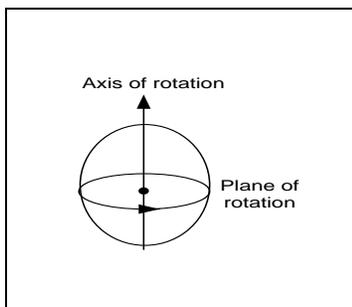Quantum spin is so strange that when Pauli first proposed it he was not believed:

Figure 3.20. Classical spin

"*... 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

In classical spin, an object in space like the earth spins in a rotation plane around an axis of rotation (Figure 3.20). Its spin on any other axis is a fraction of its total spin. One has to measure spin on any three orthogonal axes to get the total spin.

That quantum spin is the same on *any axis* is odd in classical terms but if a measurement is an all or nothing program restart, the result is always all the spin. A photon gives all its spin to any axis measurement for the same reason it gives a dot on the two-slit screen. The spin result is, as expected, Planck's constant in radians[23].

Even more strangely, a photon can spin in both directions at once, which it does just as it moves in every direction at once. Taking both angular travel paths is no different from taking all linear travel paths. Yet it can only interact once and that can't be redone. Imagine a coin spun on a table too fast to see its spin direction. The only way to find out is to stop it, and that can't be repeated unless the coin is re-spun in a new case that could be either direction again. As well as spinning both ways at once, the quantum coin spins at many table points, and in the next chapter electrons "half-spin".

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[21] 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.

[22] If Q is the quantum dimension it reduces as Q.Cos($\theta°$) where $\theta°$ is the angle from in the original plane. So at a 90° angle it has no value as Cos (90°) = 0.

[23] Spin is expressed in Plank's reduced constant of $\hbar$ (h-bar) = h/2π (in angular radians).
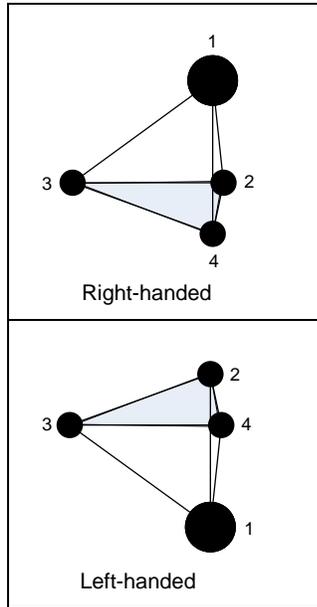
3.6. PHYSICS REVISITED

Quantum realism suggests answers to the strange findings of modern physics.

3.6.1. Superposition states

In mathematics, one solves an equation by a solution that satisfies its conditions, but solving a quantum wave equation gives a *set* of possible physical "snapshots", each with an associated probability. These evolve dynamically over time, forming at each moment an *orthogonal ensemble,* only one of which can actually occur. This mathematics has an unusual feature: if any two states are solutions so is their linear combination[24]. Single states match familiar physical events but quantum *superposition* states that never physically occur underlie the mysterious efficacy of quantum theory. They behave quite differently from physical states - it is in such a combination that one photon goes through both Young's slits at once.

For example, ammonia molecules have a pyramid shape (Figure 3.21), with a nitrogen atom apex (1) and a base of hydrogen atoms (2, 3, 4) that can manifest in either right or left-handed forms. To turn a right-handed molecule into a left-handed one, a nitrogen atom must pass through the pyramid base which is physically impossible (Feynman et al., 1977) III, p9-1. In quantum theory, if each state is valid then so are both at once, so an ammonia molecule can be left-handed one moment and right handed the next, yet it can't physically move between these states.

Figure 3.21. Ammonia molecule 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 but physical currents would cancel (Cho, 2000). When a photon spins two ways at once, in superposition, it *half-exists* each way. This is *physically* impossible but the *quantum reality* that creates physicality can spin both ways. Superposition contradicts our idea of physical reality, but is business as usual for quantum entities.

3.6.2. 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 where random photon radiation could 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. The question posed was how can a cat be both alive and dead? Or if cats can't be alive and dead, how can photons both exist and not exist? Or if photons can exist and not exist but cats can't be alive and dead, as quantum events create classical events, when does the superposition stop?
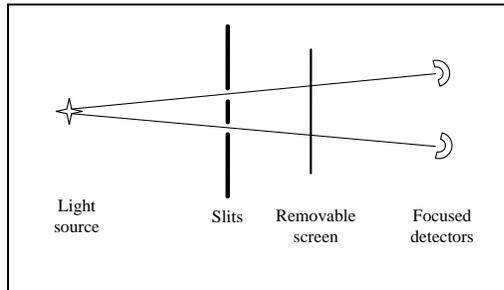
In this model, quantum events are programs spreading on a network and to observe a program wave means to overload and restart it. As we observe the world, we *formally* cause the events we see. They occur *because* we look, but the mind is not a sufficient cause, as it is in say a dream. Quantum realism isn't the *perceptualism* that neurons generate reality because *everything is observing.* Quantum collapse comes from *any* overload not just those involving our brain. A photon hitting a detector, an electron hitting a screen or light hitting a human retina are all physical "events" caused by node overloads.

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[24] If Ψ_1 and Ψ_2 are state solutions of Schrödinger's equation then $(\Psi_1 + \Psi_2)$ is also a valid solution

That everything is observing stops the infinite regress that Schrödinger assumes at the first restart, i.e. when a photon hits the detector. *Schrödinger* may not know if his cat is alive or dead, as he can't see in the box, but *the cat does*. The physical world isn't a virtual reality just for us. Quantum events were generating physical events long before our species came along to observe it all.

3.6.3. Retrospective action?

That photons travel about a foot per nanosecond allows a *delayed choice* two slit experiment. Two detection options are used, first the usual screen and second, two telescopes that focus on one slit or the other (Figure 3.22). The choice of which to use is made *after* a photon passes the slits, as the screen can be 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. The inevitable conclusion is that detectors turned on *after* the photon passed the slits decide the path that the photon took *before* that:

Figure 3.22. 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 decide the path it took, 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 actually came 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
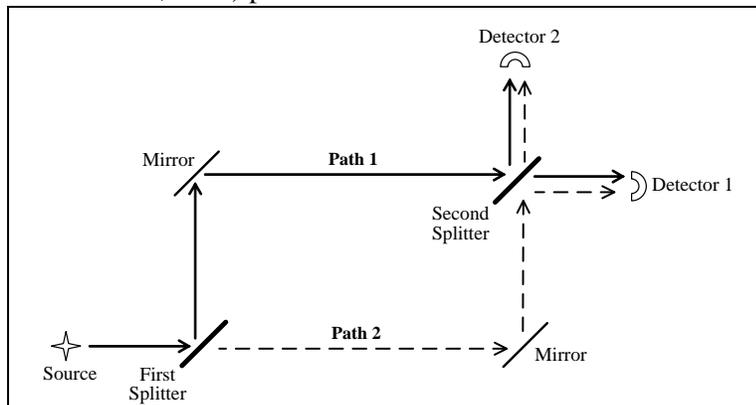
In physical realism, this means time can flow backwards and puts all physics in doubt. In quantum realism the photon program takes every path and the physical event occurs later. In computing leaving decisions to the last moment is *just in time processing*. For a screen, instances go through both slits to give interference while the telescopes restart from an instance of one or the other slits. Changing from screen to telescopes doesn't matter if the physical event occurs on arrival. That arrival is a restart based on a photon instance that took one path, whose path history is then that of the photon. A photon program spreads down every path until an instance restarts it, i.e. it is observed, and that its path is then the photon's *physical path*. So a photon's path is indeed decided when it arrives, but this implies no time reversal and the causality of physics remains intact. One can no more know where a photon will hit until it does than know which horse will win the race until it crossed the finish line.

Figure 3.23. The Mach-Zehnder interferometer

3.6.4. Non-physical detection

According to quantum theory, physics can detect an object on a path not traveled, which contradicts physical realism. In Figure 3.23, a light source shines on a beam splitter which sends half its light down *path 1* and half down *path 2*, where path 1 goes to detector 1 by a mirror and path 2 goes to

detector 2 by another mirror. The light travels both paths equally, so each detector fires half the time. If we now add a second splitter where the paths cross, to again split the light, detector 1 registers but detector 2 stays silent. This setup can register an object *without physically touching it* (Audretsch, 2004) p29.

If on path 2 is a bomb so sensitive that even one photon will explode it, the usually quiet detector 2 will sometimes respond *without exploding the bomb*. This doesn't happen if path 2 is clear, so it *proves* that something is there, but no physical light touched it or the bomb would have exploded. This isn't a poor bomb detection technique because half the time it sets the bomb off, but that it has been verified experimentally (Kwiat, Weinfurter, Herzog, Zeilinger, & Kasevich, 1995) that:

1. With two clear paths, only detector 1 fires.

2. If a receptor sensitive to *any* light is put on a path, the silent detector now sometimes fires.

3. This occurs *only* with a receptor on that path, which physically registers nothing.

Quantum theory explains this as follows: as photon quantum states evolve down the two 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.

Table 3.2. Non-physical detection (**)

Path	Existence Probability	Observation	
		No Bomb	**Bomb (path 2)**
Detector 1 by path 1	25%	Detector 1 fires	Detector 1 fires
Detector 1 by path 2	25%	Detector 1 fires	Blows bomb
Detector 2 by path 1	25%	Detector 2 never fires as out of phase path instances cancel out	Detector 2 fires**
Detector 2 by path 2	25%		Blows bomb

In quantum realism, quantum states actually occur as photon instances travel both paths to both detectors with equal probability (Table 3.2). If both paths are clear the instances reaching detector 2 interfere and it never fires, so if it does fire something must be blocking path 2.

Non-physical detection, registering what no photon has touched, is physically impossible but in our world is a proven effect. One can detect a bomb sensitive to any photon without setting it off! A *counterfactual event,* a detector that could have fired but didn't, on a path the photon could have taken but didn't, tells us what we can't possibly know. Physical realism can't explain this but quantum realism can.

3.6.5. Quantum entanglement

If a Cesium atom releases two photons in opposite directions, quantum theory says they evolve as an entangled system with zero spin, but each photon still randomly spins up or down. So however far apart they get, if one photon is spin up the other must be spin down, to match the initial spin zero. Yet if one photon *randomly* spins one way, how does the other *instantly* know to be the opposite anywhere in the universe? To Einstein, this was "*spooky action at a distance*".

Bell's inequality, a prediction based on an Einstein thought experiment (Einstein, Podolsky, & Rosen, 1935), is the definitive test of quantum theory. The test of Bell's inequality was one of the most careful experiments ever done, as befits the ultimate test of our reality and quantum theory was right yet again. It was later confirmed that this link applied even when the photons were too far apart to connect by a speed of light signal (Aspect, Grangier, & Roger, 1982). It is beyond doubt that quantum theory works, but again no physical basis was possible.

Two photons going in opposite directions are physically apart, so if each has random spin, as quantum theory says, why can't both be up or both be down? What connects them if not physicality? Nature *could* conserve spin by making one spin up and the other down from the start, but apparently this is too much trouble. It gives both photons both spins, then when one is defined, adjusts the other to match, *anywhere in the universe*. Entangled states make no physical sense, but they are now common in physics (Salart, Baas, Branciard, Gisin, & Zbinden, 2008).

Figure 3.24. Entanglement as merged processing

In quantum realism, the physical event of a Cesium atom emitting two photons is a processing reboot of two Planck programs that reload as one, i.e. entangle. To us, two photons leave a Cesium atom as distinct entities (Figure 3.24a) but actually the same merged processing runs them both (Figure 3.24b). In processing terms, a program mix of spin up and spin down instructions generates *both* sets of quantum states. If any state overloads the grid, i.e. is observed, the program it belongs to restarts there, leaving the opposite spin program to run the other photon (Figure 3.24c). Spin is conserved because the start and end code is the same.
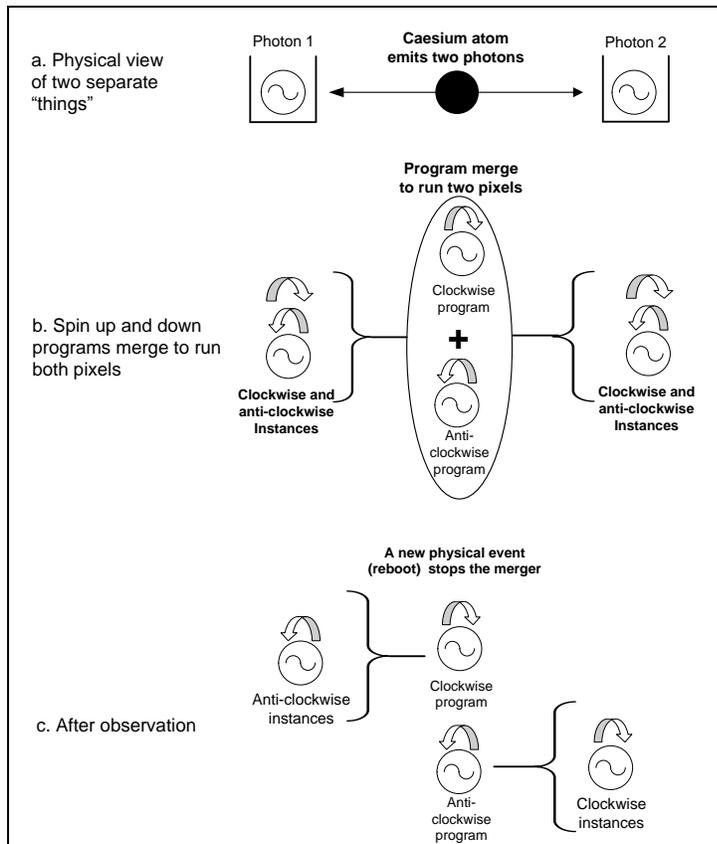
Entity programs that merge in a reboot can't know the past because it is gone. So the merged code services both "photons" jointly until another physical event starts a new entanglement. Entanglement is non-local for the same reason that quantum collapse is, that client-server effects ignore node-to-node limits like the speed of light. No matter how far apart the entangled photons are in space, they connect directly to their server source as pixels on a screen connect directly to the processing creating them. In Bose-Einstein condensates any number of quantum programs can merge in this way.

3.6.6. The holographic principle

Our eyes see depth as light from different distances arrives slightly out of phase. Flat photos just store light intensity, but holograms also store the phase differences that encode depth, e.g. a credit card hologram of 3D image. This is done by splitting laser light, and letting the half that shines on the object interfere with a matched reference half to create an interference pattern (Figure 3.25). Light later shone on that flat pattern recreates the original 3D image as a holograph. The holographic principle is that:

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

The information in a space seems to depend on its volume, but as the number of memory chips in a volume get smaller and smaller, to give more information, they form a black hole whose information depends on its surface area not its volume. The holographic principle, that all the information about *any*

physical object can be encoded on a two dimensional surface, is maintained by the behavior of black holes (Bekenstein, 2003).
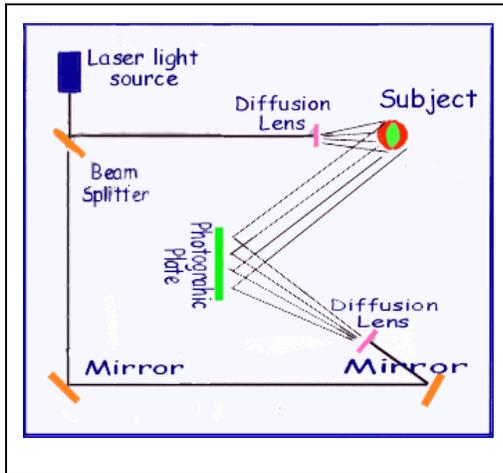

Figure 3.25. Producing a hologram[1]

A virtual world presented needs an information transfer direction. If one space dimension is that direction this leaves only two dimensions for the information to travel across. So the physical world registered at a point can always be painted on the surface of a sphere around it, since that is the structure that delivers it, i.e. quantum realism *requires* the holographic principle.

The holographic principle doesn't mean the physical world is two-dimensional, as some assume, it means it is virtual. It is a consequence of how reality *presents* not how it *operates*. The physical world as an image must be delivered across two dimensions, but "out there" light can still move with three degrees of freedom. And this is no Star Trek hologram one can enter and leave at will. Our bodies *are* its images, so if this hologram switched off, our physical bodies would disappear with it.

3.6.7. The uncertainty principle

Heisenberg's uncertainty principle is that one can't know both a quantum entity's exact position and momentum at once. This *complementarity,* that position and momentum are separately knowable but together unknowable, is part of quantum mechanics, but why does the one deny another? In quantum realism, every measurement is an information transfer:
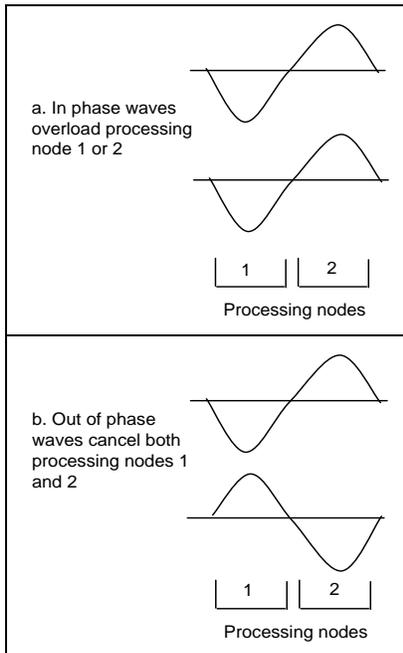

Figure 3.26. Waves interacting

"*... 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

Every physical event is essentially a digital wave interaction, namely an overload of a node of the underlying processing network. Figure 3.26 shows a simple case of waves interacting. If they are *in phase* an overload gives node position exactly but the wavelength is unknown. If they are *out of phase* they cancel so the wavelength is known but not the node position. In either case, the measurement can't repeat because the interaction changed the waves. Waves in an overload 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.

The quantum uncertainty principle comes from the nature of wave interactions, based on De Broglie's equation of momentum and wavelength[25], so one wave observing another can give position or wavelength information but not both. The information change in any physical interaction cannot be less than the processing of one Planck program, hence position plus momentum cannot be less than Planck's constant[26].

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

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

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3.7. REDEFINING REALITY

If the findings of modern physics can't be the result of physical events alone, what then?

3.7.1. The many worlds fairy tale

In quantum theory, quantum collapse is *random* so a radioactive atom can radiate a photon when it wants to and it does, for no physical reason. This fact threatens the norm that only physical events cause things, but quantum theory goes further in saying that every physical event is chosen randomly from a set of probabilities, so *every* physical act has a random component, hence physical determinism falls entirely. According to quantum theory, physical events might *relate lawfully,* by Newton's laws, but they don't entirely *cause each other*.

To meet this threat, in 1957 Everett devised the fairytale for physicists (Baggot, 2013) called *many-worlds theory* - that every quantum choice spawns an entire new universe. Now every option of a random choice actually occurs somewhere, so the *multi-verse* makes no choices and the ghost of quantum randomness is dispelled. This untestable theory was at first seen as absurd, and indeed it is, but today physicists prefer it 3:1 over the Copenhagen meaning has no meaning view (Tegmark & Wheeler, 2001) p6. So today many physicists believe that for fourteen billion years all the photons in the universe have been creating new universes with their every act, and given up to 10^{43} choices 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.

So in the time you took to read this sentence maybe a billion, billion *universes* arose just from the photons that hit your eyes! The many worlds fairy tale doesn't just offend Occam's razor, it outrages it. Actually, the idea of a *clockwork multi-verse* is just a reincarnation of the idea of a *clockwork universe* that quantum mechanics demolished last century. Deutsch's attempt to rescue this zombie theory[27] by letting a finite number of universes repartition after each choice only recovers the original problem (Deutsch, 1997), as what chooses which worlds are dropped? And why would the universe, like a doting parent with a quantum camera, want to store everything we *might* do? The ex-post-facto fairytale of many worlds shows how far physicalism will go to deny what quantum theory means.

This model interprets quantum randomness as a literal fact of our world, as a quantum server can generate random values to decide effects just as our servers do in online simulations. Physical realism requires a clockwork universe which in turn needs a clockwork multi-verse to face quantum theory, but in quantum realism the multi-verse is an unnecessary fiction.

3.7.2. The observer effect

The observer effect is the effect an observation has on the thing observed, where every observation is an interaction. The observer effect and the quantum wave give the measurement paradox that:

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

We can *never* observe a quantum wave because any attempt to do so collapses it collapses it to a physical event. Nature's *information firewall* denies us access to the quantum world. Yet how can a theory of what by definition can't be observed be science? This issue wasn't resolved last century, and so far this century is no different:

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[27] 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".

"*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.

On the one hand, physics holds that only "*...what impinges on us directly is real.*" (Mermin, 2009) p9, and on the other hand a theory about unobservable quantum states is the most successful theory in the history of science. The problem is that:

1. Quantum theory is part of physics, which is part of science,

2. If science is only about what we can observe,

3. Then as we can't observe quantum waves, now or ever, is quantum theory part of science?

If science is about physical observables then quantum theory isn't science but luckily for physics assumption #2 above is the falsehood of *logical positivism,* a naive nineteenth century ideology that often tries to masquerade as an axiom of a science. Yet science is actually based on Locke and Hume's *empiricism,* that theories of reality be *tested* by physical feedback. It follows that quantum theory is scientific because it *predicts* the physical world (empiricism), regardless of whether it *describes it* (positivism). In practice, positivism has failed every discipline that has adopted it, e.g. *behaviorism* tried to reduce psychology to physical acts but Chomsky showed that was impossible for language. Even in physics, the last bastion of positivism, the observer effect built into both quantum theory and relativity theory mean that reality will never be reducible to physical events.

The observer effect means we don't see the world objectively from above, like a bird, but subjectively from below, like a frog. In our *frogs-eye view,* we are embedded observers, unable to see relativistic changes of time or space as they change us too. If we surveyed an objective world from above there would be no observer effect, but as frogs we must interact with reality to observe it.

In quantum realism, the observer effect plus a quantum wave equals a physical event. So rather than an oddity of physics, the observer effect is how the physical world arises at all. Physical reality occurs when we interrogate quantum reality as a view arises when we click on a game screen. The long-sought boundary between the classical and quantum worlds is the "click" of observation.

The quantum quintessence that gave the first event has an observer axiomatically. If *everything is observing everything else,* a quantum world interacting with itself can create a physical world view. Last century physics rejected philosophy as impractical, but Kant (Kant, 2002) p392 noted that we only ever see a view, a *phenomenon,* not the *noumenon,* or "thing in itself", i.e. the quantum world. Yet taking physical *phenomena* (appearance) as real and the quantum *nuomena* (existence) as unreal seems to have been the wrong turn that has led physics astray for a century.

3.7.3. The quantum paradox

Our tradition of objective reality began 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 whose intrinsic properties create local effects still dominates our thought. It is the official doctrine of physics, yet the quantum states it uses ignore physical restrictions, so could they be real?

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

Do we accept as literally true a theory that:

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

Physics cannot, because to do so would make the physically impossible real:

"… 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 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; and superposed states that co-exist in physically opposite ways ignore physical incompatibility. The *world quantum theory describes can't possibly be physical,* e.g. a quantum wave can spread across a galaxy then instantly collapse to a point, but:

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

Yet when Pauli and Born defined the quantum wave amplitude as the 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

Given one reality, physical and quantum realism are mutually exclusive, so if the physical world is real the quantum world isn't, and vice-versa. So for a physical-based physics to host a non-physical theory is a contradiction, and indeed that quantum theory, the emperor of physics, has imaginary not physical clothes is of increasing concern. The quantum paradox, that quantum unreality causes physical reality, is embodied in the question:
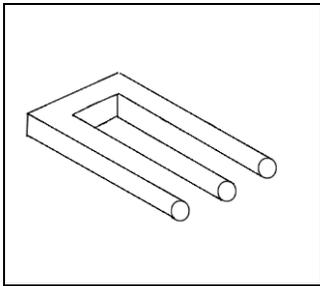

"Can something that affects real events … itself be unreal?" (Zeh, 2004) p4.

For over a century, physics has faced this paradox like a deer in headlights, attracted by the quantum brilliance but unable to abandon its traditional positivist position. Paradoxes only go away when the errors they are based on are exposed, e.g. Figure 3.27 shows an object with two square and three round prongs, depending on where you look, which is impossible.

Figure 3.27. A paradox

The answer isn't to invent some mystical "square-circle duality" but to find the error behind the impossibility - that one line can't bound both square and round prongs at once.

Likewise, the quantum paradox arises from the error of a physical realism, which contradicts both facts and logic[28]. Penrose puts the fundamental problem thus:

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

The honest answer is that they cannot, and to invent a mystical wave-particle duality to cover this up is to institutionalize illogic. It must be that quantum events create physical events, which can only be if the physical world is virtual.

3.7.4. Quantum realism

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

1. *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.

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[28] How can a world with random events be also determined? How can a physical universe *complete in itself* also *begin in a big bang*? A physics based on illogic builds paradox into its foundations.

3. *Induction*. That logical induction is a valid mode of reasoning.

The results showed that one or more of the above assumptions *must be wrong.* If realism and induction are true, then locality must be wrong. If locality and induction are true, a real world can't exist independent of our observation of it. If realism and locality are true, then logical induction must be false. Even today, 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

The resolution proposed here is to remove the word "physical" from the realism axiom, so it is:

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

This permits a quantum reality. Secondly, one must add the world physical to the locality axiom:

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

With induction intact, locality doesn't apply to non-physical effects like quantum collapse, so Bells results are no longer illogical. The cost of this solution is to remove the word physical from statements of scientific realism, such as (my deletion):

"*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

In quantum realism, science is still based on physical feedback and there is still a real world out there apart from us that we discover rather than invent. It just isn't the physical one we see. That physics got the reality tags the wrong way round doesn't change the mathematics, just the meaning.

3.7.5. The underlying reality

Thinking imaginary quantum events create real physical events is like thinking a TV show is real and the studio behind it is imaginary. TV actors often report that people meeting them think they are their onscreen persona, so it is no surprise that we think that *we see reality itself,* even with no proof. Oddly enough, no case has ever been made for physical realism, except that it is *self-evident,* but that is just 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

The physical world as an inherent reality is a meta-physical idea held without proof[29]. We hold to:

"*... 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 says that before physical reality there is a quantum reality, of which Bohr said *we must not speak*, but why not? Is it to protect the current existential canon from the challenge of quantum theory? For example, quantum collapse occurs in an instant, so entities are in-between measurements more than in them:

"*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 in unobserved, uncollapsed quantum states, by what logic are their brief moments of collapse considered reality? *Surely reality is what is there most of the time?*

---

[29] That we *register* the physical doesn't prove that only the physical *exists*.

And if quantum waves cause physical reality, isn't calling a cause unreal and its effect real backward logic? By what rationale are the states that cause physical states unreal? *Surely reality is that which causes, not what is caused?*

The current denial of quantum reality is doctrinal not logical, based on faith not facts. The facts are that there was a first event, that quantum states predict physical states and that counterfactual events occur. Table 3.3 contrasts how quantum realism and physical realism explain the behavior of light.

When matter was first attributed to unseen atoms, materialists like Mach denied they existed, since they couldn't see them. Then atoms were found to contain unseen electrons, protons, neutrons and even unseeable quarks. Now, when quantum theory says the physical world is based on probabilities, we cry "*Enough!"* and turn away. That the answer to life, the universe and everything is just a number is a step too far. So after two thousand years of scientific struggle, do we now ignore our own final conclusion?

Quantum realism takes us to a place that others shun, not to shock or amuse but to advance. It asserts what quantum theory implies: that a photon is an unseeable quantum cloud that can instantly collapse from any size; that a photon only physically arrives when observed; that it defines its physical path after it arrives; and that counterfactuals are factual.

Table 3.3. Physical vs. quantum realism explanations of light

Physical Realism	Quantum Realism
A photon is a wavicle that:	*A photon is a Planck program* that:
a) Sets imaginary positive/negative values	a) Sets values in a dimension transverse to our space
b) Moves in space as a sine wave, for some reason	b) Is rotating *on* space and moving *in* space as a sine wave
c) Moves at the fastest speed possible, for some reason	c) Moves at the network speed, so nothing can go faster
d) Never fades, as a physical wave would	d) Never fades, because grid processing sustains it
e) Collides to give *all* its energy at a point, like a particle	e) Delivers *all* the program to a node reboot
Energy. A photon's energy:	*Node transfer.* A photon's node transfer rate:
a) Decreases as its wavelength increases	a) Decreases as the program is shared by more nodes
b) Increases as its frequency increases	b) Increases as each node runs more of the program
c) Is Planck's constant times its frequency per second	c) Is a Planck program divided by its wavelength nodes
Planck's constant. Defines both the unit of energy and the unit of space, for some unknown reason	*A Planck program.* Defines a transverse circle of values that by symmetry also defines the planar circle of space
Quantum waves. A photon's quantum wave can:	*Processing waves.* A photon processing wave can:
a) Spread outwards as a sphere	a) Distribute instances outwards as a sphere
b) Pass through two slits and interfere with itself on exit	b) Pass instances through two slits that interfere on exit
c) Collapse to any point regardless of its spread	c) Restart at any reboot node regardless of its spread
d) Become a physical event, with a probability that depends on the net power of the wave at each point	d) Restart at a node with a probability that depends on how often it accesses the program server
The law of least action. A photon always takes the path of least action to a light detector, for some reason	*The law of all action.* Photon instances take every path to a detector and the first to arrive restarts the photon program
Retrospective action. A photon decides the path it took to a detector after it arrives, which is backwards causality	*Just in time action.* A photon distributing instances of itself can re-spawn from any one, complete with a physical path
Non-physical detection. We can detect an obstacle on a path not physically taken, which is physically impossible	*Quantum detection.* Blocking an alternate path prevents the interference of instances and alters the physical results
Quantum spin. A photon polarized in one plane spins:	*Four dimensional spin.* A program in four dimensions
a) With the same spin for any axis, for some reason	a) Restarts to give the same spin for any axis
b) In both directions at once, somehow	b) Can divide to spin in both directions at once

c) Into other planes, according to angle	c) Projects onto other planes according to angle as it spins
Superposition. Quantum waves can combine in physically impossible ways	*Processing combines.* Processing instances can combine in physically impossible ways if they don't overload the grid
The observer effect. The physical world seems to occur because we observe it	*The interaction effect.* The physical world, as the quantum world interface, does only occur when we observe it
Entanglement. The random spin of an entangled photon instantly defines the other's spin anywhere in the universe	*Code merging.* One server runs two entangled photons with the same merged code, until a restart divides them again
Holographic principle. All the information about a volume of space receives can be encoded on a flat surface	*Transmission principle.* All the information a node receives comes from its sphere of neighbors
Quantum paradox. Unreal quantum waves generate real physical events	*Quantum reality.* Real quantum waves generate virtual physical events

We see ourselves in the sunlight of rationality standing before a dark cave of quantum paradox,
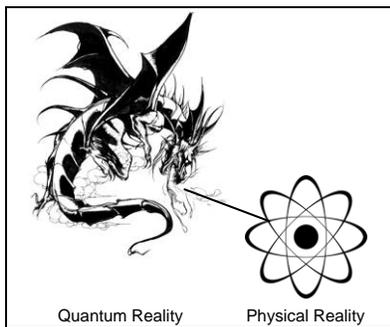

but as in Plato's cave analogy, it is the other way around: we sit in the dark cave of physicality, with our backs to the quantum sunlight, taking the shadows it casts on the wall of space as reality. Quantum theory and relativity have loosed the chains that bind us, but who will turn and look? Einstein did, but the quantum brilliance baffled him. Bohr did, but wearing his impenetrable Copenhagen suit he saw only his own reflection. The quantum light is currently quarantined behind a wall of arcane equations, and the acolytes who harvest it must first declare that *the quantum world has no meaning.* Quantum nihilism is leading physics nowhere just as nihilism in life leads nowhere, and to say that one's own best theory means nothing is indeed nihilism[30].

Figure 3.28. The quantum smoke

Quantum theory today makes no more sense now than when it was invented last century. The next hundred years will be the same until quantum theory is recognized as a *reality description.* To Wheeler, the quantum world was *a great smoky dragon* (Wheeler, 1983). Quantum realism just adds that the physical world is its smoke (Figure 3.28). The quantum world is no shadow world existing alongside physical reality. It is the real world whose shadow is the physical world we see.

QUESTIONS

The following discussion questions are answered in this chapter:

1. Could electro-magnetic oscillations occur in a physical direction?
2. What is the same for every photon in the entire electro-magnetic spectrum?
3. Does the "imaginary" dimension of complex numbers actually exist?
4. Why does light uninterrupted never slow down?
5. Why is the speed of light a maximum for any medium?
6. What is energy in processing terms?
7. Why does all energy come in Planck units?
8. How does a light wave deliver all its energy instantly at a point?
9. How can one photon go through both Young's slits at once?
10. How can a quantum wave collapse instantly to a point, regardless of spatial extent?
11. What are counterfactuals? How do we know they exist?
12. Is a photon a wave or a particle, or both? If it is both, how can that be?

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[30] Throughout history, the nihilism that *nothing really matters* has been an excuse to do what you want.

13. How can a photon of polarized light pass entirely though a filter nearly at right angles to it?

14. How does a photon always find the shortest path to a light detector?

15. Why is a photon's spin on any axis always the same?

16. Is non-physical knowing, knowing a thing without physical contact, possible?

17. How can a photon choose the physical path it took to a detector *when* it arrives?

18. Why is a superposition of physically incompatible quantum states possible?

19. Can we ever see quantum waves directly?

20. Why does quantum realism imply the holographic principle?

21. How can entangled photons instantly affect each other anywhere in the universe?

22. According to quantum theory, observation creates physical reality, so is life just a dream?

23. If quantum states create physical states, which are real? Can both be real?

24. Where do random quantum choices come from?

25. What is the quantum paradox, and how does quantum realism resolve it?

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