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

In the last chapter, 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 that a photon is *processing* spreading on a quantum network that is the:

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

This network isn't what we see but what creates what we see, including time, space, mass, charge and energy. It doesn't exist in space nor operate in time because 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 these properties from a photon as processing 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 saw 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 cancels the crest of another. The end result is a forward moving envelope that at a distance from the source acts like

[1] For the latest chapter versions see http://thephysicalworldisvirtual.com/.

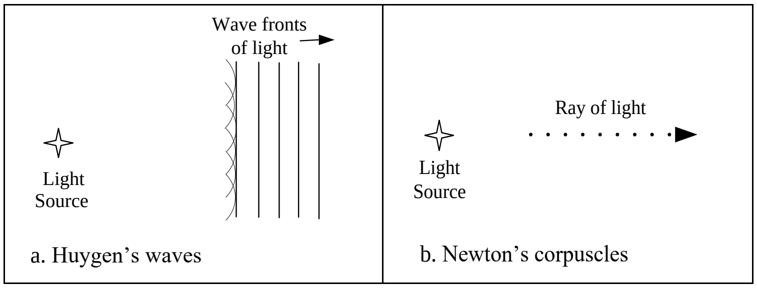

Figure 3.1. a. Huygen's wave front. b. Newton's corpuscles

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 concluded that light is a wave with a wavelength, until 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 both 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

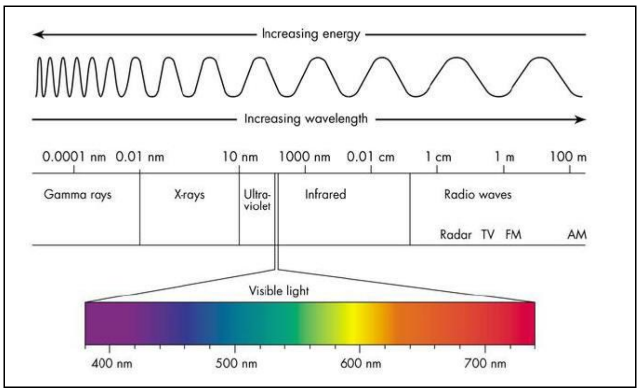

Figure 3.2. The electro-magnetic spectrum

Even today, 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 only 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 is many photons polarized on different planes on the same axis of movement.

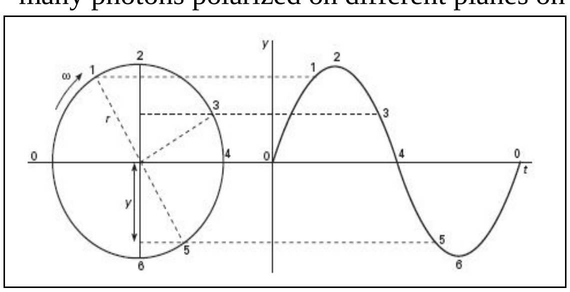

Figure 3.3. A circle maps to a sine wave

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 and in mathematics a sine wave 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).

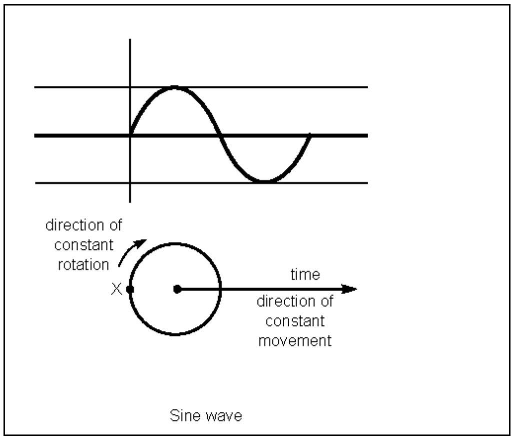

Figure 3.4. A sine wave is a moving rotation

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?

Waves vibrate a medium so if light is a wave 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.

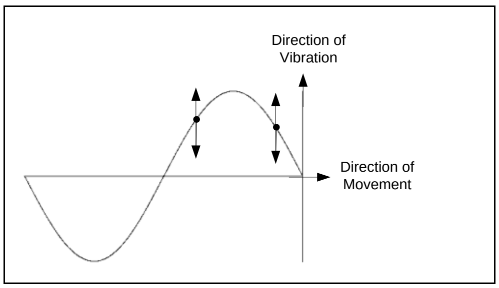

Figure 3.5. Waves vibrate ***on*** *a surface*

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. According to current physics, light is an immense Ponzi scheme!

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]. Yet ancient light[3] that has traveled the universe for billions of years to reach us still arrives at the speed of light with its amplitude undiminished. Light as a *frictionless wave of nothing* isn't physically possible, and a century of physics still hasn't answered the question:

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

In quantum realism, light is a processing wave spreading on a quantum network that always runs anyway. Empty space as null processing is no more empty than an idle computer is idle[4], so the:

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

Physical waves fade by friction but light doesn't fade because it is processing passed on by a quantum network that never stops. Equally electricity and magnetism aren't "mutual causes" but rather both effects of something more fundamental, namely quantum processing.

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

[3] Cosmic background radiation

[4] 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 speed of space

Einstein deduced the speed of light from how the world behaves, but why is it just that speed and no other[5]? 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

"*Because it just is*" has never been a very satisfactory answer in science. In this model, light moves at a fixed speed because the network refresh rate is finite, just as every processor has a finite rate, e.g. a 5GHz computer runs 5,000,000,000 cycles per second. Light goes from one node to the next each cycle so its speed is limited by the network speed, i.e. its cycle rate. The speed of light is a property of the vacuum that transmits it, so it should be called the *speed of space*[6].

If the speed of light is constant why does it slow down 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, so when it moves in empty space we must call it a wave of nothing! In quantum realism, whether light travels in glass, water or empty space the medium doesn't change – it is always the quantum network!' In glass or water, the grid must process matter as well as light so slows down, as a computer game frame-rate drops if it is busy with other things. The quantum network 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. 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.

3.2.5. The surface of space

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 move on a lake, but in three dimensions not two. Space as a hyper-sphere surface can have dimples and dents just like a sphere, so a photon can be a transverse harmonic oscillation moving *on* space, as complex number theory says it is[7]. In current physics light rotates in an *unreal* space, but in quantum realism it rotates in a real quantum space.

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[5] 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?

[6] 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).

[7] 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 4*i* = 5.

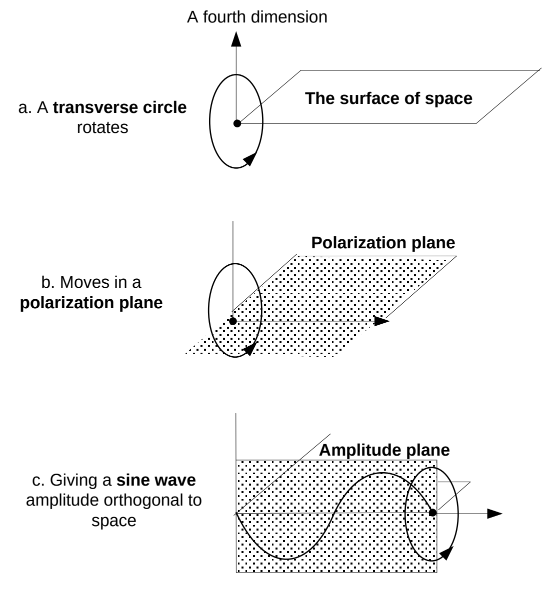

Figure 3.6. A transverse circle moving on space

In Abbot's story, Flatlanders who lived on a two dimensional surface could only conceive a 3D sphere as a set of expanding and contracting circles passing through their reality (Abbott, 1884). A circle rotation moving *on* their plane would appear to them as a sine wave in an unreal dimension just as electro-magnetism appears to us. When it comes to light, we are *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). Complex numbers explain electro-magnetism because it really does vibrate in 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 plane into which quantum waves vibrate because we are made of those waves, and a wave cannot leave the surface it vibrates upon.

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

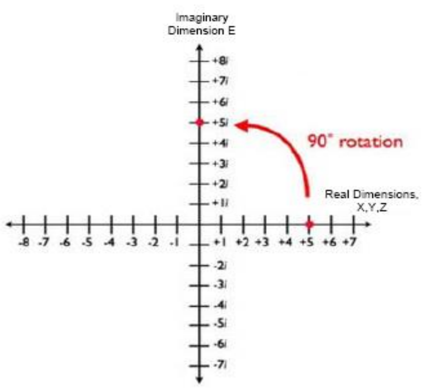

Figure 3.7. Complex rotations

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, a field that creates a force at every point in space. Likewise, an electric field sets values at every point, 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 has 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. Physics today calls it Ψ, the *quantum function,* and Chapter 4 describes how this one "field" rules all the others.

3.2.7. Planck processing

The set of operations a processor can do is its *command set*, so add one might be in the command set of your computer. As computing evolved to include databases and networks we had to add new operations giving *complex instruction set computing* (CISC). Then it was found that reduced instruction set computing (RISC) is simpler and better. The proposed command set for the quantum network 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 processing behind a transverse circle, one operation can generate the entire electro-magnetic spectrum.

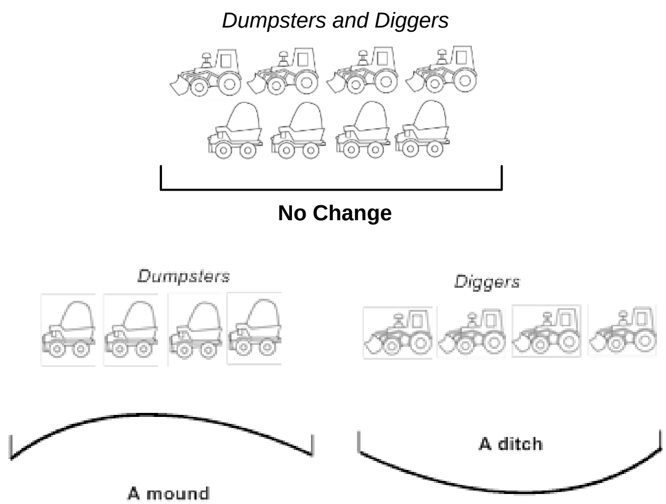

Figure 3.8. Processing distributed

One Planck program running in one node is nothing because its "up" and "down" displacements cancel but the same processing divided between two nodes is something. Imagine a work party made up of 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 one site the result after a day is no net change, since the dumpsters added as much dirt as the diggers removed. But if they divide so the diggers are at one spot and dumpsters at another, the result is a hole and a mound, and if the party moves on each night this up/down pattern moves on the surface, like a wave.

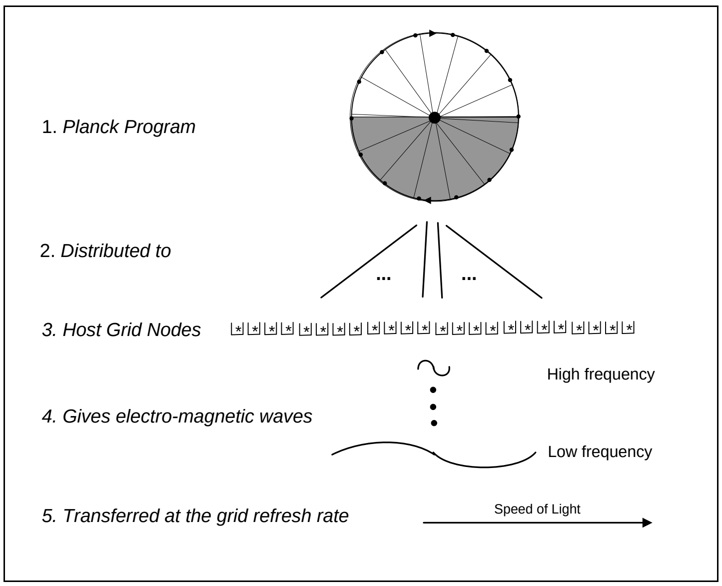

Figure 3.9. Light is a Planck program spread out

Likewise, Planck processing setting a circle of values in one node each cycle gives "nothing", but the same spread over two nodes gives an up-down effect that passed on is a wave. This processing spread over more nodes gives the sine waves of the electro-magnetic spectrum (Figure 3.9). Every photon frequency is based on the same processing passed on, so as a new node begins another finishes and the net processing doesn't change.

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

3.2.8. Energy is the node processing 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, should 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 which 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 *node processing rate*. A photon with a short wavelength has less nodes to run the same Planck program, so each does more per cycle, i.e. has more energy. A long wavelength photon with more nodes to run the same program allocates less processing per node, so has less energy. Higher light frequencies have more energy because fewer nodes must do the same processing work.

Planck's constant as the core quantum network command must be the smallest physical event. No network act can be smaller than a command set act, so it is the *minimum* energy transfer. A quantum entity can only change as the network acts upon it, and here that must be in Planck amounts. In this model, Planck's constant also represents the total processing of every photon which must be *divided* over the nodes in its wavelength. If one adjusts for the different units by the speed of light, this implies that a photon's energy is its frequency *multiplied by* Planck's constant[9].

A photon's energy 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 entire electro-magnetic spectrum, from radio-waves to gamma rays, is the same quantum processing more or less spread out!

3.2.9. The photon packet

A photon hitting a photographic plate creates a dot but a wave arriving should be a smear. Radio waves are many meters long and so should take time to arrive even at light speed, but they don't. If they did, in the delay between wave's first hit and the rest arriving the tail could hit something else, so one photon could hit twice, 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

A quantum wave delivers *all* its energy *instantly* at a point, but a physical wave must deliver its energy over its wavelength. However distributed processing can instantly "arrive" at a point if it restarts there, so quantum collapse can be a processing restart (see 3.3.5).

3.2.10. The quantum network density

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 model, Planck's constant is the basic energy unit because it represents the basic command of the quantum network, to set a *transverse circle* of values. In the last chapter, movement depended on a node's *planar circle* of neighbors, that by Pythagoras's theorem define the "distance" between nodes.

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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 to reflect the refresh rate of 10^{43} cycles per second.

The number of nodes in a transverse circle decides the basic energy unit and the number of nodes in a planar circle decides the size of space.

If *the quantum network is symmetric*, transverse and planar circles are the same size, so Planck's constant as the energy of a transverse circle also defines the planar circle that sets the size of space. In network terms, the number of connections each node has to others is the network density. Planck's constant links space and energy because it represents the *density of the quantum network* that creates both.

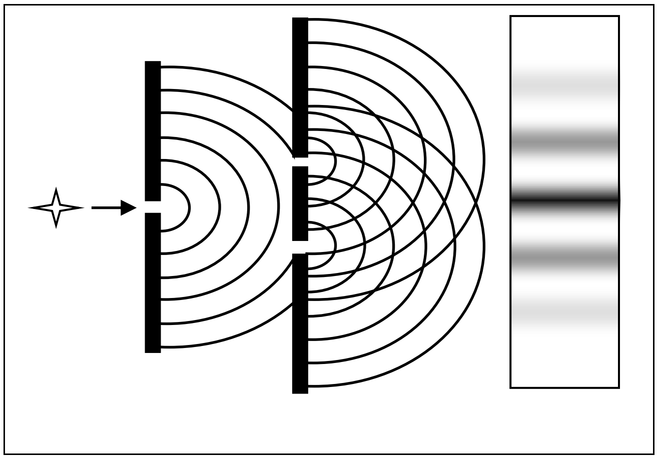


Figure 3.10. Young's double slit experiment

3.3. IMPLICATIONS

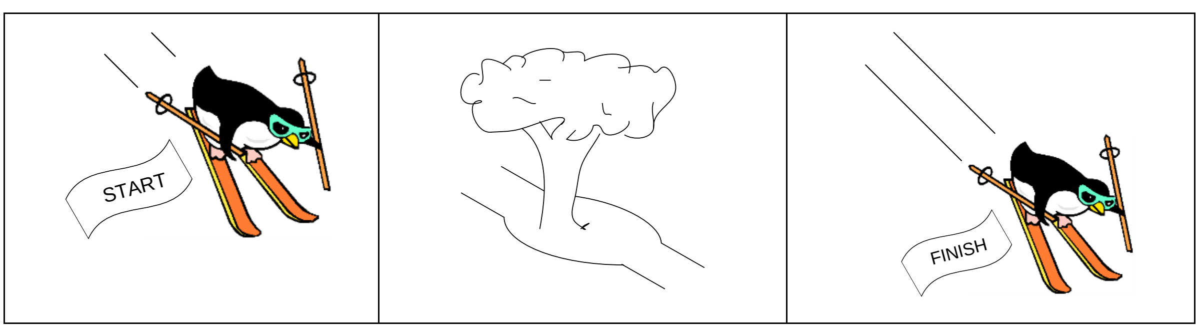
3.3.1. Young's experiment

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 like a particle? Conversely, 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 interference pattern emerge?

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).



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

Figure 3.11. Wave-particle duality

3.3.2. The Copenhagen compromise

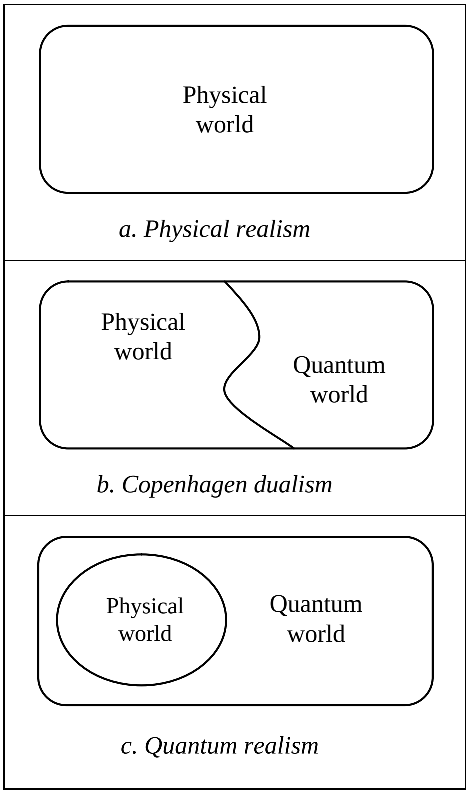


Figure 3.12. a. Physical monism, b. Bohr's dualism, c. Quantum monism

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 when we don't look as long as it is a particle when we do. This convenience lets physics use the formula that fits even though a particle is never a wave nor a wave a particle. In no physical pond do rippling waves suddenly become point particles when seen, yet Bohr successfully sold the *big lie*[10] that light is a *wavicle.* As Gell-Mann said 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 both deny physical realism (Figure 3.12a) so Bohr let the quantum world co-exist with the physical world so physics could carry on calculating (Figure 3.12b) (Audretsch, 2004) p14). In private he denied the quantum world but in public he recognized it in order to use its equations. In contrast, quantum realism rejects the Copenhagen compromise, proposing instead that classical mechanics is a subset of quantum mechanics (Figure 3.12c), and that physical events are a subset of quantum events.

3.3.3. How come the quantum?

As Feynman famously said:

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

Quantum theory explains 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 shrinks to a point when observed, prompting Wheeler's question: *How come the quantum*?

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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.

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 will *always* be 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 predict physical events don't exist, is unsatisfactory.
2. *What is quantum collapse?* Why does a quantum wave collapse when 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.

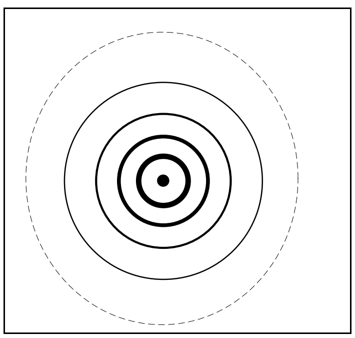

Figure 3.13. Pond ripples

The quantum field

In quantum realism, any processing 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.

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 quantum network will follow the same law but with no friction. The *processing flux* is constant but as it distributes on a sphere surface its power reduces 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 propagate at the speed of light, again as fields do. The next chapter attributes all the fields of the standard model to one quantum field.

Processing shared runs slower not less

A physical wave reduces in amplitude as its wavelength increases but processing that spreads just slows down. If a circular program is shared between two nodes, 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, two men sharing a shovel only dig half a hole each. In general, processing *distributed runs slower not less,* so as a quantum wave spreads frequency reduces not amplitude.

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

A photon "exists" in processing terms by running on the quantum network, regardless of how its processing is distributed. Whether an electron wave is spread over a galaxy or collapsed in a particle reboot point doesn't matter. For processing, *where* it runs is irrelevant, as long as *it does run*.

In network terms, server processing running on a client node is an *instance. Instantiation* is an object orientated design method where screen objects inherit processing from a source class[12]. A photon as processing can run *instances* of itself along its wavelength that once started eventually complete, however slowly. It spreads on the quantum network as a cloud of instances sharing the same processing.

Processing can restart instantly

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 two options. Either the path the particle travelled before it hit was hidden or there was another physical cause:

"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

Einstein raised this problem and Bohr dismissed it but it still haunts physics today. Quantum theory isn't incomplete because it always works and it isn't physically plausible because quantum waves are physically impossible. Every attempt to "reify" quantum states (make them physical) has failed. So this is a problem that current physics will *never* resolve! In contrast, quantum waves as processing waves is not only plausible but processing spreading on a network can restart from any point, just 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 particle bias. We see a photon interact in one place and assume it moves the same way, but that is just tacked onto the facts. Quantum theory asserts that photons *travel* as quantum waves but *interact* at a point (nodes). Its critics couldn't fault this logic because there is no fault. We know a photon hits the screen at a point but we don't know how it got there. What can move like a wave but arrive like a point particle? Processing can because it can spread and restart at any node.

To say a photon *has* wave function is the stubborn illusion of a singular *thing*. Rather *the photon is the quantum wave* and the "particle" we see is just a *view* created on demand. Classical mechanics describes the physical world stage but quantum mechanics describes the reality backstage.

3.3.5. What is quantum collapse?

Quantum waves collapse into physical particles but physics doesn't know 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 because 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 do this? How can two events *anywhere* in the universe be *instantly coordinated*?

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

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* shared on a network can indeed restart at any node point that overloads and *reboots*. If quantum entities are processing spreading on a quantum network, they must eventually overload a node giving reboot that:

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

b. *Conserves processing*. When a distributed program is restarted in a reboot the processing before and after is the same.

c. *Allows change*. When the processing that caused the node overload restarts in a reboot it 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. 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 any node overloads it reboots, i.e. tries to restart *all* its processing. For a server with many client nodes, not every reboot can succeed. The first node to request a server reboot restarts the *entire* photon program, and becomes where the photon "hits" the screen.

Quantum entities are processes not things. When two electrons collide, we assume the same "particles" leave as entered but actually they are brand new, just off the quantum press. Physical events annihilate and create quantum entities but conserving processing maintains the illusion of continuity.

How can a quantum wave spread over a galaxy *instantly* collapse to any point in it? In processing terms, a program doesn't "go to" a screen pixel to change it. It can change any screen point directly, and

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[13]	*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[14]	*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[15]	*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

likewise a quantum server can alter pixels[16] anywhere in the universe "instantly". The node-to-node link that defines the speed of light isn't relevant to the server-client link that governs quantum collapse.

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

[14] 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 $P = P_1 + P_2 + 2\sqrt{P_1 P_2}\,\text{Cos}(\theta)$, where θ is the interference phase difference.

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

[16] Which are quantum states.

3.3.6. The quantum lottery

In quantum theory, the *power* of a quantum wave at any point defines the *probability* a quantum entity physically exists there. In quantum realism, a quantum wave is a processing wave and a physical event is when a node of the quantum network overloads and restarts the processing, so what decides that? Servers have many clients so a quantum server response to a client node reboot request could be:

1. *Grant access*. The server restarts the processing in that node in a physical event that denies all other nodes access for that cycle, i.e. collapses the quantum wave.
2. *No response*. The server doesn't respond as it is busy elsewhere, so node ignores the overload and just carries regardless, 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 quantum server we can't access. It is also probabilistic because nodes with more processing from a quantum entity get more access to it. When many nodes reboot, the first to initiate a server restart locks out all the others. It wins the prize of *being the photon* for that cycle and all the other instances wither on the grid. The photon as processing never dies because it can be born again from any of its legion of instances.

When a photon meets a screen, quantum theory calculates the hits probabilities as follows:

a. Its equations describe how the quantum wave evolves.
b. If it reaches the same point by different paths, positive/negative values add to a net result.
c. The net result at each point squared is the *probability* it physically exists there.

Quantum realism interprets this as calculating the processing demand, follows:

a. The photon's processing spreads on the quantum network as a 3D wave.
b. If it reaches the same point by different paths, positive and negative amplitudes cancel before the server is accessed.
c. The power of a wave is its amplitude squared and for a processing wave its power defines server access[17]. Client nodes with more processing demand more server access and so are more likely to successfully reboot from it, i.e. host a physical event.

For nodes to cancel positive and negative server amplitudes locally is an expected efficiency and that more processing to do gives more server access is also expected. The probability of a physical event is the quantum amplitude squared because quantum waves are processing waves. When many client nodes request a restart from one quantum entity the choice is random *to us* because it involves server activity we have no access to.

Table 3.1 interprets 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 server supports instances that pass through both slits then interfere as they leave, even for one photon at a time. This interference alters the processing demand which alters the probability that a node will get a server response when it overloads. The first screen node to overload and reboot the server is where the photon "hits". 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 other slit half the time. This answers questions like:

a. *Does the photon go through both slits at once?* Yes, photon instances go through both slits.
b. *Does it arrive at one screen point?* Yes, photon processing restarts at one screen node (point).
c. *Did it take a particular path?* Yes, the instance that caused the reboot took a specific path.

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

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

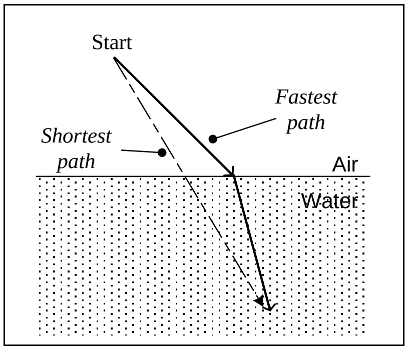

Figure 3.16. Light refracts

In a nutshell, quantum realism is that quantum theory is literally true. In a virtual reality, *processing* creates *pixels* an *observer* sees but what can see quantum state pixels? Only another quantum entity can, and it can only "observe" by interacting to overload the same node causing a reboot that restarts them both in a physical event.

3.4. LIGHT TAKES EVERY PATH

Processing on a network can spread as a wave but "arrive" by restarting at a point like a particle, so it explains how light behaves.

3.4.1. Light is a wave

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, and indeed photons detected by screens at different distances aren't in a perfect straight line but randomly spread about (Figure 3.15). A physical photon particle would have to travel in a zigzag path to explain this!

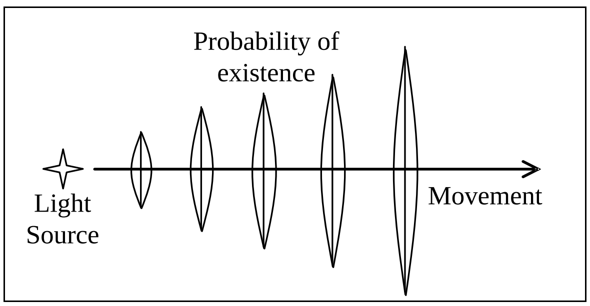

Figure 3.14. A *photon probability of existence*

3.4.2. The law of least action

Newton rejected Huygens's wave view of light:

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

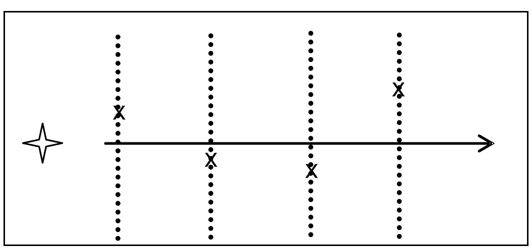

Figure 3.15. Detection of a "ray" of light

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 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] 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*".

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

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 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.

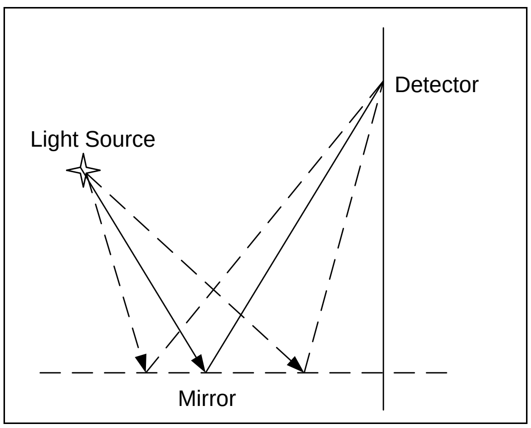

Figure 3.17. Principle of least action

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. Like the rest of quantum theory, it was a physical impossibility that just happened to work perfectly.

In this model, Feynman's method works because it describes what the photon actually does. Photon instances do take *all available paths* and physical reality is decided down the line by the first restart. The instance that happens to take the fastest path to a detector reincarnates as the photon in a physical event, making its path the 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. It is practical to take them all and *pick the fastest later,* as in a virtual reality calculating and taking a path are the same thing. This is real-time processing.

As the photon travels it knows nothing in advance so spreads instances down every path and the fastest to arrive at a detector to cause an overload becomes "the photon". The server just handles node clients on a first come first served basis and quantum collapse is the necessary information garbage collection. A photon reaching a detector by the fastest route isn't a solitary particle magically knowing the best way but a quantum ensemble that explores every path and 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 a quantum processing wave in a quantum dimension can also explain quantum spin.

3.5.1. Quantum directions

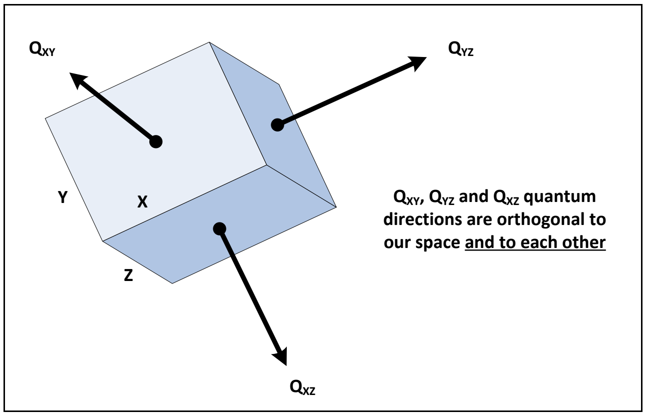

Figure 3.18. Quantum directions

In current physics, a photon is a complex value rotating 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.

Now 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). Light can vibrate in three ways at a point, at right angles to the three planes through it. A filter that blocks vertically polarized light doesn't block horizontal polarized light, because they oscillate 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, so it has a rotation:

a. *Axis*. Around which the spin occurs, and which doesn't change with the spin.

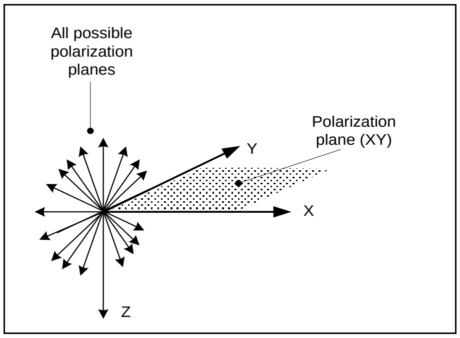

Figure 3.19. Polarization planes

a. *Plane*. In which the spin occurs, whose dimensions swap values as the structure spins.

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

If a photon *spins on its movement axis*, as a bullet from a gun does, it spins into all the planes of its movement axis (Figure 3.19). Yet the direction of its quantum vibration doesn't change because it isn't on the rotation plane[21], so its quantum

---

[19] Feynman's: "*Whatever is not explicitly forbidden must happen*" is Gellman's 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.

[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.

amplitude projects into any 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. 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 81º 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 has many service requests so if a client request isn't answered it's just dropped. A spinning photon will pass through a filter if by chance its blocked instances don't get server access, the others instances just 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:

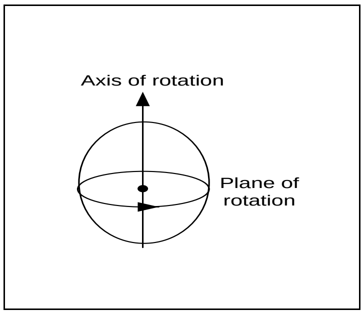

Figure 3.20. Classical spin

"*… 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 must measure spin on 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".

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 the quantum wave equation gives a *set* of 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.

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[22] If Q is the quantum dimension it reduces as Q.Cos(θ°) where θ° 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 ħ (h-bar) = h/2π (in angular radians).

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

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.

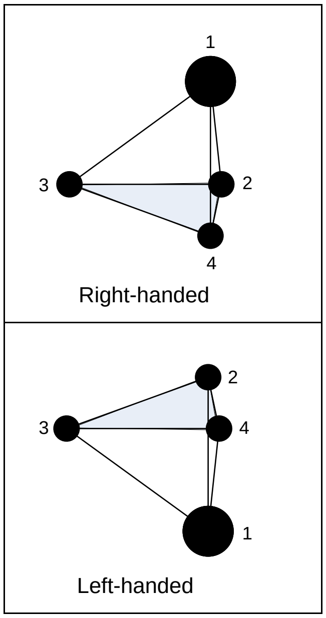

Figure 3.21. Ammonia molecule states

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). A photon that spins two ways at once *half-exists* each way. Superposition is a *physical* impossibility but a *quantum reality*. It denies 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 processing spreads on the network until it restarts, i.e. "observes". When we observe the world we *formally* cause what we see. It happens *because* we look but that isn't a *sufficient* cause, i.e. there really is something out there. Quantum realism isn't solipsism, that we create physical reality as we create a dream. Instead, *everything observes everything else* so quantum collapse isn't just for us. Quantum events generated physical events long before our species came along. This universe isn't a virtual reality just for us, as if humanity doesn't "work" other sentient beings will arise.

So a photon hitting a detector, an electron hitting a screen and light hitting a retina are all quantum overloads that give physical events. This stops the infinite regress that Schrödinger assumes, so if a photon hits the detector in a physical event, the cat dies. *Schrödinger* doesn't know if his cat lives as he can't see in the box but *the cat does*. Schrödinger's problem is that he only sees from his point of view.

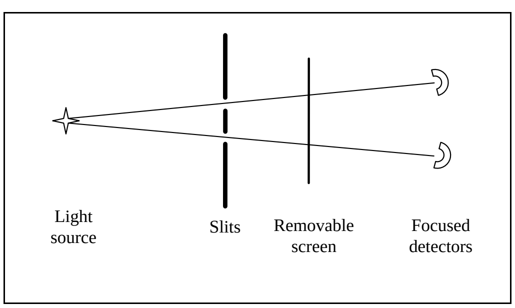

Figure 3.22. Delayed choice experiment

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:

> "*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

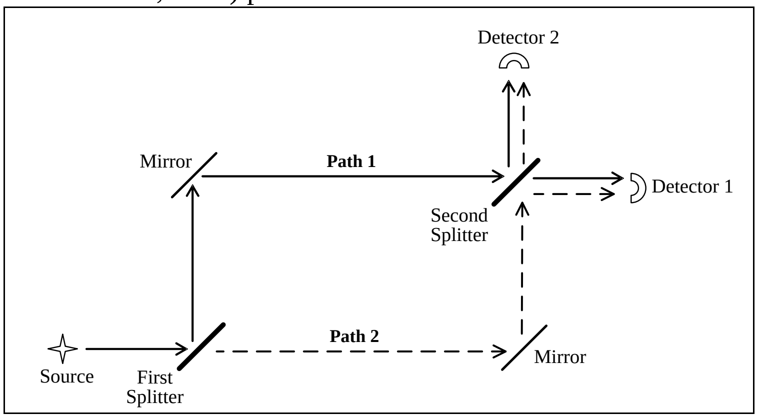

Figure 3.23. The Mach-Zehnder interferometer

According to physical realism, this experiment implies that time can flow backwards and that puts all of physics in doubt. In contrast quantum realism sees photon processing take every path to leave physical events until later. Leaving processing choices to the last moment is a *just in time* (JIT) system in current computing. If a screen is there photon instances go through both slits to give interference. If it is removed after the photons go through the slits the photon just carries on spreading until an instance hits one telescope to restart from there, which instance only went through one slit. Swapping the screen in and out doesn't matter because the physical event occurs on arrival. That arrival is a restart based on a photon instance that took one path, whose path history becomes that of the photon. Photon instances spread down every path until one of them restarts the photon, i.e. is observed, when its path becomes the photon's *physical path*. So that a photon's path is decided when it arrives 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 a race before the finish line.

3.6.4. Non-physical detection

In quantum theory one can detect an object using a path it didn't travel, another scientific fact that denies 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 one adds 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 path 2 has a bomb so sensitive that even one photon will explode it, the usually quiet detector 2 sometimes responds *without exploding the bomb.* This never happens if path 2 is clear. So the detector 2 response *proves* something is on path 2, but no physical light touched the bomb or made it explode[25]. 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.

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[25] This is a poor bomb detection technique because half the time it sets the bomb off!

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, photon instances travel both paths to both detectors with equal probability (Table 3.2). If both paths are clear, instances reaching detector 2 interfere and it never fires, so if it does fire something must be blocking path 2. This *non-physical detection* registers what hasn't been touched, which is physically impossible, but in our world it happens! A *counterfactual event,* a detector that could have fired but didn't, on a path the photon didn't take, tells us what we can't possibly know. Physical realism can't explain this and never will.

3.6.5. Quantum entanglement

When a Cesium atom releases two photons in opposite directions, quantum theory says they evolve as an entangled system with zero spin, even though 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 give zero spin. Yet if a photon spins *randomly* 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. This was one of the most careful experiments ever done, as befits the ultimate test of reality and quantum theory was right yet again. It was 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). Again, quantum theory works but no physical basis is possible!

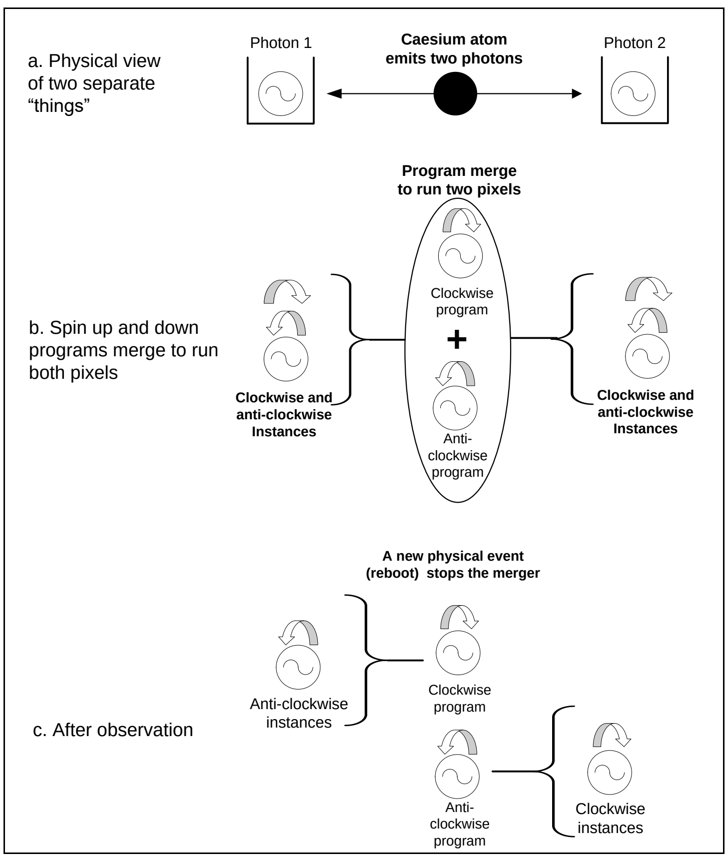

Figure 3.24. Entanglement as merged processing

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

Quantum realism sees a Cesium atom emitting two photons as restarting the processing of two photons in one node. The reboot reloads both processes as one, i.e. entangles them, with a net spin of zero. To us, the photons leaving the Cesium atom are distinct entities (Figure 3.24a) but at the server level the same processing runs them both (Figure 3.24b). An equal mix of spin commands generates *both* photon instances. If an instance from either photon restarts it, i.e. is observed, it occurs with that spin, leaving the remaining opposite spin processing to run the other photon (Figure 3.24c). Spin is conserved because the start and end processing is the same.

Quantum processing that merges in a reboot can't know the past because it is gone, so it 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 a CPU. In Bose-Einstein condensates any number of quantum programs can merge in this way.

3.6.6. The holographic principle

Our eyes see depth because light from different distances arrives slightly out of phase. Flat photos 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).

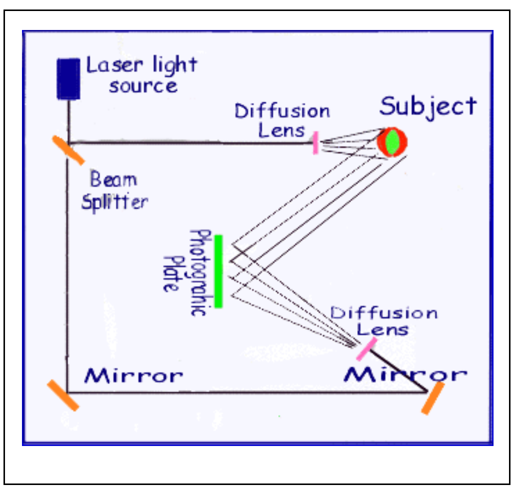

Figure 3.25. Producing a hologram[1]

A virtual world must be observed from some angle, so if quantum entities that move in three dimensions also observe this leaves only two dimensions for the information transfer. So in our reality, the physical world registered at a point can always be painted on the surface of a sphere around it, because that is the structure that delivers it. That the physical world only exists when observed *requires* the holographic principle.

The holographic principle doesn't make the physical world two-dimensional as some say. It is a consequence of how reality *presents* not how it *operates*. A physical world that *presents* an image must deliver across two dimensions, but "out there" still has three degrees of freedom. This is no Star Trek hologram we can enter and leave at will because our bodies *are* its images. If this hologram were switched off, the continuity of our physical body reality would immediately stop.

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. The *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:

"*… 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

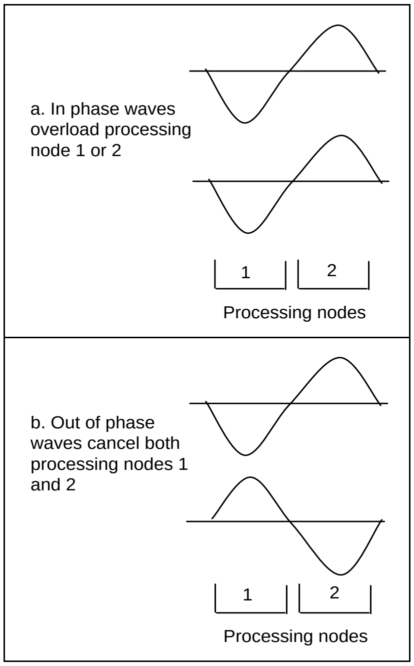

Figure 3.26. Waves interacting

Every physical event is essentially a digital wave interaction, when a node of the quantum network overloads. 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[26]. One wave observing another can give position or wavelength information but not both. The information change in any physical interaction can't be less than one Planck program, so position plus momentum can't be less than Planck's constant[27].

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 for no physical reason. This fact threatens the primacy of physical causes, but quantum theory goes further, saying that every physical event is a random pick from a probability set. If *every* physical act has a random component, physical determinism falls entirely because physical events *relate lawfully* but don't actually *cause each other*.

To meet this threat, in 1957 Everett devised a fairytale for physicists (Baggot, 2013) called *many-worlds theory*, that every quantum choice spawns an entire new universe. That every quantum choice occurs somewhere dispels the ghost of quantum randomness, if you believe in a *multi-verse heaven*. Everett's idea was first seen as absurd, as it is, but today physicists prefer it 3:1 over the Copenhagen compromise because something is better than nothing (Tegmark & Wheeler, 2001) p6. Current physics believes that for fourteen billion years all the photons in the universe have created new universes with their every act! With up to 10^{43} universes 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.

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

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

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 *clockwork multi-verse* just reincarnates the *clockwork universe* that quantum mechanics demolished last century. Deutsch's attempt to rescue this zombie theory[28] by letting a finite number of universes repartition after each choice only recovers the original problem, as what picks which worlds are dropped (Deutsch, 1997)? Why would the universe, like a doting parent with a quantum camera, want to store everything we *might* do? The ex-post-facto many worlds fairytale shows how far physical realism will go to deny quantum realism.

3.7.2. The observer effect

The observer effect is that observation changes the thing observed because every observation is an interaction. The observer effect applied to quantum waves gives the measurement paradox that:

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

We can't observe a quantum wave because any attempt to do so collapses it to a physical event. Nature's *firewall* denies us access to the quantum world, so how can a theory of what can't be observed be science? This issue wasn't resolved last century and so far this century is no different:

> "*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, current physics holds that only "*…what impinges on us directly is real*." (Mermin, 2009) p9, while 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. Science is entirely about what we can observe,
3. Since we can't observe quantum waves, quantum theory isn't part of science!

If science was entirely about physical observables then quantum theory wouldn't be science, but lucky for physics assumption #2 above is a naive nineteenth century idea that often tries to masquerade as an axiom of a science. Science is based on Locke and Hume's *empiricism*, that scientific theories must be *tested* by physical feedback, not on the *logical positivism* error that theories must describe physical things. Quantum theory is scientific because it *predicts* physical events (empiricism) regardless of whether it *describes* physical events (logical positivism). Positivism has failed every discipline that has tried it, e.g. *behaviorism* tried to reduce psychology to physical acts until Chomsky found that was impossible for language. In computing, that everything can reduce to hardware denies software, human-computer-interaction (HCI) and socio-technical systems like Twitter. Even in physics, the last bastion of positivism, the observer effect built into quantum theory and relativity theory[29] mean that reality will never reduce to physical events.

We don't see the world objectively from above like a bird but subjectively from below like a frog. Our *frogs-eye view* makes us embedded observers, unable to see relativistic changes of time or space because they change us too. An objective world surveyed from above would have no observer effect, but in our frog-world we must interact with reality to observe it.

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[28] 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".

[29] Quantum collapse requires observer and relativity requires an observer frame of reference.

In quantum realism, the observer effect isn't an oddity of physics but fundamental to it. Physical reality is when we interrogate quantum reality, as a view is produced when we click in a game. The long-sought boundary between the classical and quantum worlds is the "click" of observation.

As *everything is observing everything else* the quantum world interacts with itself to create the physical world as a set of views. Physics ignores philosophy, 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. Taking physical *phenomena* (appearance) as real and quantum *noumena* (existence) as unreal was 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, so why not apply it to the quantum states of quantum theory?

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

However this would accept a theory as literally true that:

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

Physics currently cannot accept that what is physically impossible is real because:

"*... 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. The bottom line is that 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

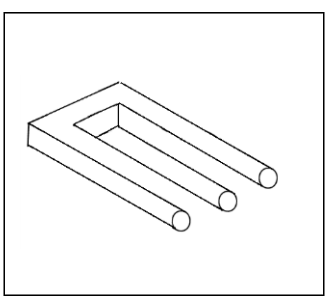

Figure 3.27. A paradox

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. Nor can a policy of physicality openly support a non-physical theory, as the quantum emperor of physics has imaginary not physical clothes. That quantum unreality causes physical reality, called the quantum paradox, 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 afraid to abandon its positivist tradition. Paradoxes only go away when the errors they are based on are exposed, e.g. Figure 3.27 has two square or three round prongs depending on where you look, which is impossible. The answer isn't some mystical "square-circle duality" but to recognize the illogic that one line can't bound both square and round prongs at once.

Likewise, the quantum paradox arises from the illogic behind physical realism[30], for:

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

The honest answer is that they cannot. To pretend that it can be so is to institutionalize illogic. Quantum events do create physical events, and that can only mean that the physical world is virtual.

3.7.4. Quantum realism

Bell's experiment was a test of 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.
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 is to remove the word "physical" from axiom #1, so it is:

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

This permits a quantum reality. Then add the world physical to axiom #2:

That no physical influence of any kind can propagate faster than the speed of light.

Now, with induction intact, locality doesn't apply to non-physical effects like quantum collapse, so Bells results aren't illogical. This removes 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. 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. Physics as a science works fine without physical realism. Swapping the reality tags doesn't change the mathematics, just the meaning.

3.7.5. The unmeasured reality

Thinking that physical events created by quantum events are real is like thinking a TV show is real but the studio behind it is imaginary. People meeting TV actors often treat them like their onscreen

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

persona so it is no surprise the we call physical reality real. Not only has no case has ever been made for physical realism, no-one is looking for proof because it is *self-evident.* Yet this 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[31]:

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

Science advances by questioning assumptions not sanctifying them. In quantum theory, before physical reality there is quantum reality, of which Bohr said *we must not speak*, to protect physics. But if physics is science, since when was science about protecting its traditions? For example, quantum collapse is an instant, so entities are mostly in-between measurements:

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

If entities exist mostly 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?* If quantum waves cause physical reality, isn't them unreal and their effect real backward logic? By what rationale is what causes a physical effect unreal? *Surely reality is the cause not the effect?*

The current denial of quantum reality is doctrinal not logical, based on faith not facts, because there was a first event, quantum randomness does occur and quantum waves do predict physical effects. When matter was first attributed to unseen atoms, physicists like Mach denied them since they couldn't see them, but today we accept atoms that contain unseen electrons, protons, neutrons and quarks. Yet 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. After two thousand years of scientific struggle, do we now walk away from our own final conclusion?

Quantum realism says that light is indeed a quantum wave that instantly restarts when observed and chooses a physical path after it arrives, as quantum theory says, because a processing wave can do that. Table 3.3 contrasts how quantum realism and physical realism explain the behavior of light.

Table 3.3. Physical vs. quantum realism explanations of light

Physical Realism	**Quantum Realism**
A photon is a wavicle that: a) Sets imaginary positive/negative values b) Moves in space as a sine wave, for an unknown reason c) Has the fastest speed possible, for an unknown reason d) Doesn't fade by friction, as a physical wave would e) Collides to give *all* its energy at a point, like a particle	*A photon is a Planck program* that: a) Sets values in a dimension transverse to space b) Rotates *on* space and moves *in* space as a sine wave c) Moves at the network speed, so nothing can go faster d) Never fades because processing sustains it e) Delivers *all* its processing to a point reboot/restart
Energy. A photon's energy: a) Decreases as its wavelength increases b) Increases as its frequency increases c) Is Planck's constant times frequency per second	*Energy*. A photon's processing rate per node: a) Decreases as its processing is shared by more nodes b) Increases as each node runs the program faster c) Is a Planck program divided by wavelength nodes
Planck's constant. Is both the unit of energy and the unit	*A Planck program*. Is a transverse circle of values and by

[31] That we *register* the physical doesn't prove that it is real.

of space, for some unknown reason	symmetry also a planar circle of space
Quantum waves. A photon's quantum wave: a) Spreads outwards as a sphere b) Passes through two slits to interfere with itself c) Collapses to any point regardless of its spread d) Becomes a physical event with a probability that depends on the net power of the wave at each point	*Processing waves*. A photon's processing wave: a) Distributes instances outwards as a sphere b) Passes instances through two slits that interfere on exit c) Restarts at any reboot node regardless of its spread d) Restarts with a probability that depends on server access which depends on net processing demand at each point
The law of least action. Light always takes the path of least action to a detector, for some unknown reason	*The law of all action.* Light takes every path to a detector and the first to arrive restarts the photon 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 can re-spawn from any one, complete with a physical path
Non-physical detection. One can detect an obstacle on a path not physically taken, which is physically impossible	*Quantum detection.* Blocking an alternate path prevents quantum interference and alters the physical results
Quantum spin. A photon polarized in one plane spins: a) With the same spin for any axis, for some reason b) In both directions at once, somehow c) Into other planes, according to angle	*Quantum spin.* Quantum processing in four dimensions a) Restarts give the total spin for any axis b) Can spread two ways at once c) Projects onto other planes according to angle as it spins
Superposition. Quantum waves can combine in physically impossible ways	*Processing combines.* Processing can combine in physically impossible ways if there is no overload
The observer effect. The physical world seems to occur because we observe it	*The interaction effect.* The physical world is an interface created so the quantum world *can* observe
Entanglement. The random spin of an entangled photon instantly defines the other's spin anywhere in the universe	*Merging.* Entangled photons merge their processing, so the same server runs both until the next restart
Holographic principle. All the information about a point of space receives can be encoded on a surface around it	*Transmission principle.* All the information a node receives comes from its sphere of neighbors
Quantum paradox. Unreal quantum waves generate real physical events	*Quantum reality.* Real quantum waves generate virtual physical events

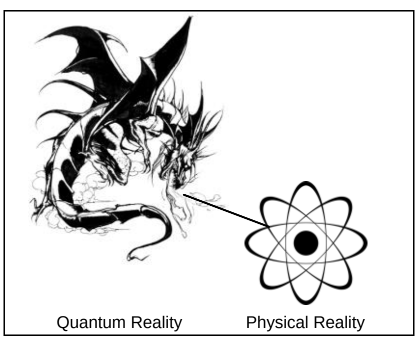

Figure 3.28. The quantum dragon

3.7.6. The smoky dragon

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 cave of physicality with our backs to the quantum sunlight, calling the shadows it casts on the wall of space reality. Quantum theory and relativity have loosed the chains that bind us, but who will turn and look? Einstein did, but the quantum brilliance blinded him. Bohr did but in 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 deny *the quantum world exists.* Yet to say that one's own best theory is about nothing is nihilism, and quantum nihilism is leading physics nowhere[32].

[32] Nihilism in general leads nowhere. Throughout history, that *nothing really matters* has been just an excuse to do what you want.

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

QUESTIONS

The following discussion questions are answered in this chapter:

1. Why is it impossible for electro-magnetic oscillations to occur in a physical direction?
2. What is the same for every photon in the electro-magnetic spectrum?
3. How can 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 its 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?
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. How is non-physical knowing, knowing a thing without physical contact, possible?
17. How does a photon choose the physical path it took to a detector *when* it arrives?
18. Why is it possible for physically incompatible quantum states to overlap, i.e. superpose?
19. Why can’t we ever see quantum waves directly?
20. How 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 waves cause physical effects, why can’t the latter 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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