Chapter 2. Creating Space and Time

Brian Whitworth, New Zealand

"To me every hour of the light and dark is a miracle.
Every cubic inch of space is a miracle"

Walt Whitman

A virtual world can represent a space and time to its inhabitants. This chapter analyzes how a virtual world could generate a space and time that would appear to its residents as ours does to us.

2.1. QUANTUM PROCESSING

Quantum theory describes the quantum processes that generate physical events. We know that quantum processing occurs because quantum computers use it and they work, but how does it run and what does it do? This section suggests that it runs on a quantum network and is, in our terms, the creation of processing.

2.1.1. The quantum network

The idea that physical events are generated is radical but not new, given the following proposals:

1. *Fredkin.* Proposed that for physical events to be generated "*…only requires one far-fetched assumption: there is this place, Other, that hosts the engine that 'runs' the physics*." (Fredkin, 2005) p275.
2. *Wilczek.* Proposed that what generates physical events is "*… the Grid, that ur-stuff that underlies physical reality*" (Wilczek, 2008 p111).
3. *Wheeler*. Proposed that some sort of processing generates matter *"… every physical quantity, every it, derives its ultimate significance from bits … a conclusion which we epitomize in the phrase, it from bit*." (Wheeler, 1989).
4. *D'Espagnat*. Proposed that a "*veiled reality*" generates time, space, and matter (D'Espagnat, 1995).
5. *Campbell.* Proposed that a "*Big Computer*" generates our reality (Campbell, 2003).
6. *Barbour*. Proposed that time is generated by a landscape where "*The mists come and go, changing constantly over a landscape that itself never changes*" (Barbour, 1999) p230.

These proposals suggest that something else generates physical events, so let Fredkin's engine, Wilczek's ur-grid, Wheeler's bit source, D'Espagnat's veiled reality, Campbell's big computer, and Barbour's landscape all refer to a primal network that existed before our universe began. Our cellphone networks consist of stations that actively support local phones, where each station connects to its neighbors (Figure 2.1), so let the network proposed be the same, except each station is a point of space that supports local entities not phones. Space itself is then a network of points, just as Feynman viewed it according to Hiley:

> "*I remember … Richard Feynman … saying that he thought of a point in space-time as being like a computer with an input and output connecting neighboring points*." (Davies & Brown, 1999), p138.

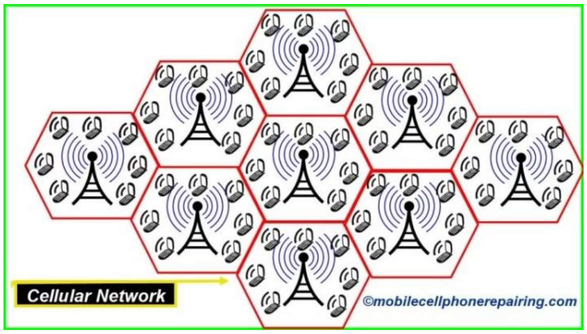


Figure 2.1. A cellphone network

Feynman imagined space as a network, whose points had inputs and outputs like a computer. Let us therefore also imagine space as a network, which is empty when its output is null, and when it isn't, shows something else, like a photon or electron. Behind this concept is the same processing that runs our quantum computers.

But if quantum processing generates matter, is matter just information, as Wheelers It from Bit implies? Before exploring how a quantum network could create a space and time like ours, let us clarify what information is.

2.1.2. What is information?

The nature of information was specified by information theory when Shannon and Weaver defined it in terms of binary choices between physical states[1] (Shannon & Weaver, 1949). One choice from two states is a bit of information, two choices is two bits, and so on. Eight bits, or a byte, is eight choices, so eight electronic on/off switches can store one byte. Eight switches have 256 possible combinations, so one byte can store about one text character. All our kilobytes and megabytes are based on choices between physical states.

If only physical states exist, then all information depends on them, so there is no software without hardware. Information stored as choices between matter states needs matter to exist, so to think that information can also create matter is like thinking a daughter can give birth to her mother, which is impossible.

A choice of one state, or no choice at all, is zero bits, so anything fixed one way contains no information. It follows that a physical book contains no information in itself because it only exists one way. This seems wrong but it isn't, as hieroglyphics that no-one can read do indeed contain no information. Symbols only contain information if we can read them, which requires a decoding context. For example, the text you are reading now requires the decoding context of the English language, so if you don't know English, you get no information. If you change the decoding context, like reading every 10th letter, the result will be different information from the same text.

Information theory defines the decoding context of a physical signal as the number of physical states it was chosen from. This number defines the amount of information sent, so one electronic pulse sent down a wire can represent one bit, or it can be one byte as ASCII "1", or as the first word in a dictionary it can be many bytes. The amount of information in a signal depends not only on the signal itself, but also on its decoding context. If it weren't so, data compression couldn't store the same data in a smaller signal, but it can by better decoding. In general, the information in a physical signal is undefined until its decoding context is known. The transfer of information between a sender and receiver requires an agreed decoding context, so a receiver can only extract the information a sender put in a signal if they know how to read it.

Given the above definition, processing can be defined as the act of changing information by making new choices. Writing a book is then processing, as it can be written in many ways, and reading a book is also processing, as it can be read in many ways. Processing lets us save data in a physical state and reload it later, given a decoding context. Information is then static, while processing is a dynamic activity.

2.1.3. Reloading reality

If our world is information, can it be saved and restored like a game world? To do that requires a decoding context based on our world, which is circular as McCabe explains:

> *"All our digital simulations need an interpretive context to define what represents what. All these contexts derive from the physical world. Hence the physical world cannot also be the output of such a simulation."* (McCabe, 2005).

[1] Mathematically, Information $I = Log_2(N)$, for N choice options.

The physical world can't both cause information and be caused by it, so we can't define information in physical terms then call physical events an information output. This follows from information theory as defined by Shannon and Weaver, but to understand it, imagine our universe frozen at a point in time, as many physical states. What then could load and restart it? A physical state has no information in itself, so who or what could decode it? Not us, as we would be frozen too, along with the universe! A simulation based on physical events can't create those events as information, as McCabe says, nor can it reload a frozen universe. In contrast, a laptop can save and reload a game, because its operation doesn't depend on game events in any way.

Matter can't be information if information depends on matter, so some suggest that minds are information encoded by brains, so emulating a brain would clone it (Sandburg & Bostrom, 2008), so we could copy our mind to a younger body, or live forever as a hologram. Yet there is no evidence at all that computers experience events as minds do. A computer can create a hologram that acts and talks like a dead person, but no-one is there experiencing those events. Emulating a dead relative doesn't resurrect him or her, any more than a video or photo of them does, so saving and reloading the information of past events doesn't recreate them.

But if a person's brain was copied exactly, atom for atom, wouldn't that copy their consciousness? Nature provides the answer because it has already done it. Identical twins are essentially physical clones of the same egg, but they are different people with different experiences. It follows that a physical clone of me doesn't make another me, but another person entirely, as I can't experience their life, nor they mine. Chapter 6 critiques the silicon chip speculation in more detail (6.3.11).

Something is wrong with the idea of reloading reality, and it is the belief that only matter is real. If that was true, a perfect physical copy of me would be another me, but it isn't. Instead, it is like reloading a game for another player. Even if one day we managed to copy atoms perfectly, cloning a person to another location would create their twin, not them, so if the source atoms remained, there would be two people in two bodies, not one. To really reload a physical event, we must copy what causes it, so can quantum reality be saved and reloaded?

2.1.4. Quantum cloning

Clearly a photo of me isn't me, nor is a movie of me, and even a perfect physical copy of me isn't me but my twin. Copying matter doesn't copy reality but if quantum events cause physical events, as quantum theory suggests, why not copy them? Can quantum cloning save and reload reality?

Unfortunately, the *quantum no-cloning theorem* explicitly excludes this (Wootters & Zurek, 1982). To copy a quantum state, it must first be observed but according to quantum theory, observing a quantum wave restarts it at a point, which destroys it. Observing a quantum state makes it disappear, so quantum cloning is impossible.

To understand why, consider a laptop with a central processing unit (CPU) plus memory registers to store data. The CPU can copy the data in its memory registers but not its own state, because the act of doing so changes that state before the copy. It can input and output data but it can't copy itself, because trying to read itself, changes itself. It follows that a network of CPUs only with no memory registers, as quantum theory describes, can't copy itself by the logic above. Quantum theory then implies the no-cloning theorem because it describes a network of processors without data storage!

The quantum network proposed has no storage because it is constantly active. The quantum waves upon it also never stop, as they are either expanding, or restarting to expand again, in the observations we call physical events. It is like a star that constantly shines without pause, so it can't save or reload itself.

Our Internet network uses memory buffers to handle overloads but a quantum network doesn't have this luxury. Cell-phones save and reload physical states but the quantum network can't store or reload quantum states by the no-cloning theorem. It must run by itself alone, with no backups, buffers, or saves to fall back on if it fails, so it doesn't operate as our networks do.

This means that McCabe's argument against virtualism doesn't apply to a quantum network that isn't based on information. Information needs physical states to exist but quantum events don't. They can create physical events because they don't depend on them, as quantum processing has no physical context.

One might expect processing powerful enough to generate physical events could save a copy of itself, but it can't. It follows that all talk of uploading or downloading universes, minds, or ourselves is just wishful thinking. The quantum network has nowhere to store anything, so we live in a world of events that can't be saved, not things that can (Seibt, 2024).

2.1.5. Processing waves

The quantum network never stops, nor do the waves upon it. A quantum wave, of light or matter, runs at a point, then is passed on to its neighbors, that also run and pass it on, and so on. Each point runs and passes on what it gets, in a ripple of processing that travels at light speed because the quantum network is so fast. This ripple, or quantum wave, is a processing wave, and in the next chapter these waves explain the miracle of light.

A processing wave can spread like a wave across network points but if any point reboots, it will restart again, just as turning a smartphone off and on again reboots and restarts it. A phone will reboot when it overloads, so reverse engineering suggests that a network point overloading will reboot and restart the quantum wave. It follows that quantum waves spreading on a network will eventually overload a point that will reboot and restart them again. Chapter 4 details how these reboots can give rise to matter.

In this view, photons are like apps that spread on a network. We call an app that spreads on the Internet a virus, but a photon on the quantum network spreads like a virus until a reboot restarts it. As will be seen, this model explains how quantum waves spread, collapse, and restart in network terms.

But while our networks transfer information, the quantum network transfers processing, and while our apps generate processing, quantum "apps" generate processing. The principles are the same, but the quantum network is based on processing while our networks are based on information. For example, quantum waves spread processing not information, so quantum computers are more powerful than physical computers. Doubling the power of a physical computer needs double the bits, but adding just one qubit to a quantum computer doubles its power[2]. Comparing quantum processing to physical processing is like comparing a nuclear bomb to a classical bomb.

Our computers are lightning fast but each bit is still a choice between two physical states. In contrast, a qubit can choose both states at once, so while a physical electron can spin up or down, its quantum version can spin up and down at the same time. Schrödinger's example of a cat that is alive and dead at the same time shows how strange this is to us (3.8.2). Quantum currents can even travel both ways around a circuit at once, even though it is physically impossible (Cho, 2000).

Quantum theory's description of photons and electrons, as waves that restart when observed in physical events, predicts their behavior brilliantly, so Heisenberg imagined the quantum world as one of possibilities:

"*The atoms or elementary particles themselves are not real; they form a world of potentialities or possibilities rather than one of things or facts.*" (Rosenblum & Kuttner, 2006), p104.

Einstein ridiculed this because it was physically impossible, so Bohr proposed the compromise we have today, that the quantum world is imaginary but we can still use its equations:

"*There is no quantum world. There is only an abstract quantum physical description.*" (Petersen, 1963).

Essentially, the physical events quantum theory predicts are real, so we can use its equations, but what it describes is imaginary, so no explanations are possible. This example of doublethink lets physicists use equations based on quantum waves that they say don't exist! If astronomers used equations based on the earth orbiting the sun but denied that it did, they would be ridiculed, but current physics allows it!

Despite its relegation to the realm of fantasy, the revelation that quantum events cause physical events was the greatest discovery of last century, on a par with evolution the century before, and that the earth orbits the sun

[2] A quantum computer of N qubits equates to a classical computer of 2^N bits.

centuries earlier. But while religion opposed the earlier advances, physics is the denier this time. That orthodoxy denies innovation is no surprise, but who expected the orthodoxy to be physics itself?

If quantum events generate physical events, the physical world we see reflects a quantum world we can't see. Most of us think that we see reality but the evidence is that we only see outputs. That space and time are also generated would explain why they curve and dilate, so let us explore how that could be.

2.2. CREATING SPACE

This section considers how a quantum network could create a space like ours but to reverse engineer our space, its properties must be specified. It might seem strange to talk of the properties of space, but different virtual worlds have different requirements. For example, our world needs a space that can expand indefinitely without problems.

2.2.1. Is space continuous?

In language, a continuous thing exists without gaps, and in mathematics, a continuous line has no breaks. Space is then continuous if it has no gaps or breaks in it, however small. Yet continuity makes movement illogical, as Zeno's paradoxes (Mazur, 2008) illustrated two thousand years ago:

1. If a tortoise running from a hare sequentially occupies infinite points of space, the hare can never catch it, because every time it gets to where the tortoise was, it has moved a little further on; OR
2. If space and time aren't continuous, there must be an instant when the arrow from a bow is at a fixed unmoving position. If so, how can many such instants beget movement?

To deny the first paradox exposes one to the second, and vice-versa. Zeno's paradoxes resurface today as infinities in field equations. For example, continuity requires an electron to exist at a point with no size, which makes its mass infinitely dense. Physics avoids these infinities by a mathematical trick called renormalization, which attributes all particle interactions to other particles. Dirac described this tactic as follows:

"*Sensible mathematics involves neglecting a quantity when it turns out to be small - not neglecting it just because it is infinitely great and you do not want it!*" (Kragh, 1990), p184.

Feynman was even blunter:

"No matter how clever the word, it is what I call a dippy process! ... I suspect that renormalization is not mathematically legitimate." (Richard Feynman, 1985), p128.

Physicists ignore the infinities of continuity because they want to, not because there is a reason to do so:

"*... although we habitually assume that there is a continuum of points of space and time this is just an assumption that is ... convenient ... There is no deep reason to believe that space and time are continuous, rather than discrete...*" (Barrow, 2007), p57.

There is no reason to believe that space is continuous, but there is a reason to think it isn't. The quantum of quantum theory means that shorter wavelengths of light only have more energy up to the limit of Planck's constant. This limit, called the Planck length, is then, according to quantum theory, the shortest length possible.

It follows that repeatedly dividing space gives a smallest length that can't be divided further. Just as closely inspecting a TV screen gives irreducible dots, closely inspecting our space gives irreducible Planck lengths, so it is digital not continuous. Not only does repeatedly dividing space give a pixel that can't be split, repeatedly dividing time gives a cycle that can't be paused, so it is also digital. This then answers Zeno's paradoxes as follows:

There is indeed an instant when the arrow is in a fixed, unmoving position, but there is still movement because the next cycle generates the next physical position. Equally the hare cannot get closer to the turtle forever, because there is a minimum pixel distance that can't be divided, so the hare catches the turtle.

A digital world of irreducible pixels and indivisible ticks makes the infinities of continuity disappear, like ghosts in the day, because denying the infinitely small avoids the infinitely large. If our world is a digital reality, its resolution is 10^{-33} meters and its refresh rate is 10^{-43} seconds, or Planck length and time respectively. The quantum network is very fine, but not infinitely so, and quantum processing is very fast, but not infinitely so either.

2.2.2. Is space nothing?

If matter exists, and space is just its absence, is it nothing at all? The greatest minds of physics have wondered whether space exists, and in particular:

If all the matter in the universe disappeared, would space still exist?

If space is something it would, but if it is nothing at all, it wouldn't. For Newton, space was the canvas upon which God painted, so without matter it would exist as an empty canvas. In contrast, Leibniz didn't believe that God would make what had no properties, so he defined space relative to matter, just as distance is defined by two marks on a platinum-iridium bar in Paris. It followed that objects only move with respect to each other, so without matter there would be no space.

Newton's reply to Leibniz was a spinning bucket of water (Figure 2.2). At first the bucket spins not the water, then the water also spins and presses up against the side to make a concave surface. If the water spins with respect to another object, what is it? It can't be the bucket because initially, when it spins relative to the water, the surface is flat, and later, when it is concave, the bucket and the water spin at the same speed. In a universe where all objects move relative to other objects, a spinning bucket should be indistinguishable from one that is still. Another example is an ice skater spinning in a stadium whose arms splay out by the spin. If this movement is relative the stadium, why doesn't spinning the stadium make the skater's arms splay? Such examples suggest that the skater is spinning relative to space, not matter (Greene, 2004), p32.

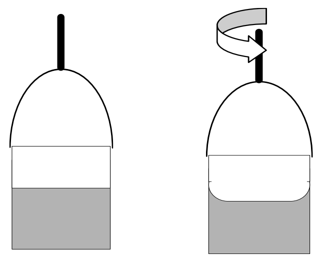


Figure 2.2 Newton's' bucket.

This seemed to settle the matter, so space is something, until Einstein showed that the movement of objects actually is relative. Mach then resurrected Leibniz's idea to be that the water in Newton's bucket rotated with respect to all the matter of the universe, so in a truly empty universe it would stay flat and a spinning skater's arms wouldn't splay. This theory can't be tested, because we can't empty the universe, but his willingness to speculate without evidence shows how disturbing some physicists find the idea that space is:

"…*substantial enough to provide the ultimate absolute benchmark for motion.*" (Greene, 2004), p37.

The current verdict of physics is that "*space-time is a something*" (Greene, 2004), p75, so it could be a quantum network output, but how would it register object collisions? Computing suggests two options:

1. *Centralized.* A central processor registers every object's absolute position and compares them every cycle to deduce a collision for those at the same point. To its inhabitants, this space would seem to be continuous and to have no existence in itself, but the processing needed increases geometrically with the number of objects as each is compared to every other. For the atoms and electrons in our universe, the load is enormous, so a central processor could overload and collapse the whole system.

2. *Decentralized.* Each network point is allocated a finite processing capacity to handle local events, so a collision occurs when one gets more processing than it can handle and overloads. To its inhabitants, this space would seem discontinuous and to exist apart from the objects in it. This approach wastes processing on empty space but means that the system as a whole never fails.

Current computing prefers the decentralized option because then the whole system never fails. Our Internet is decentralized for that reason. Given that our universe has run for fourteen billion years without failing, for a virtual space, the second option is expected, that each point of space has a finite capacity to handle whatever passes through it. When nothing does, that processing still runs but gives a null result. Empty space is then null processing not nothing, so if every object disappeared, it would still exist, just as a screen still exists even when it is blank.

It follows that empty space isn't the passive canvas of Newton, because null processing is active not passive, nor is it the nothingness of Leibniz, because null processing is something not nothing.

2.2.3. Is space linear?

If empty space is something not nothing, then what is it? Quantum simulations describe spacetime as follows:

"*…we think of empty spacetime as some immaterial substance, consisting of a very large number of minute, structureless pieces, and if we let these … interact with one another according to simple rules … they will spontaneously arrange themselves into a whole that in many ways looks like the observed universe.*" (Ambjorn et al., 2008), p25.

This approach is compatible with the idea that space is a network of indivisible points that interact with each other according to simple rules, as proposed here. What then are the services that space provides in order to look like our space? The following are suggested:

1. *Locations*. Points that define when objects are in the same locality and so interact.
2. *Directions.* The neighbors a point can interact with define possible directions from that point.
3. *Dimensions*. The number of independent degrees of freedom that the space can extend into.

Locations, directions, and dimensions are services that a space that looks like ours must provide. For example, in Wilson loop networks, each point is a volume of our space, and in Penrose spin networks, points interact in events that have input and output directions (Penrose, 1972). The need for dimensions is illustrated by their use in geometry. About two thousand years ago, the Greek Euclid created geometry by defining the structure of space as follows. He began with a point location of no dimensions that extended in one direction to make a line, that then extended at right angles to give a plane, that again extended to give a cube. This defined our space as having three linear dimensions, so every point could be represented by three number coordinates (x, y, z).

The resulting Cartesian System worked so well for geometry that it became the standard, but it doesn't suit all cases. For example, war-gamers adapt Euclid's space to the two dimensions of a game board by using hexagons not squares, as they give more directions of attack. Yet most simulations still assume a Cartesian or linear space, including loop quantum gravity (Smolin, 2001), cellular automata (Wolfram, 2002), and lattice simulations (Case, Rajan, & Shende, 2001) but to work on a network, a Cartesian space needs:

1. *A maximum size:* The size of the space must be known in advance, to allocate coordinate memory.
2. *A zero-point origin*: The space has to have absolute centre, or (0,0,0) point, within itself.

However, our space behaves in a way that satisfies neither of these requirements.

The maximum size requirement arises because the memory of linear coordinates depends on the network size. For example, a point stored as (2,9,8) in a 9-unit cube, must be stored as (002,009,008) in a 999-unit cube, so it needs more memory. This limit caused the Y2K bug that experts worried would crash our systems in the year 2000. The problem was that early computers stored years as two digits, to save memory, so 1949 was stored as "49", but that meant that the year 2000 was stored as "00", just as the year 1900 was. Even now, airline booking systems can mistake a 101-year-old woman for a baby for this reason.

If our space is a generated Cartesian space, its maximum size had to be set before the first event to avoid a Y2K bug. But our space has been expanding at the speed of light for billions of years and still is, with no end in sight, so its final size is undefined. A Cartesian space the size of our universe should have crashed by now, but it hasn't, so our space can't have linear dimensions.

The zero-point origin requirement arises because a Cartesian space needs a (0,0,0) point within itself, so when Hubble showed that every star and galaxy is receding from us, assuming a Cartesian space made our Earth the origin of the universe! But our planet only began recently, so it can't be so! The discovery that our space is expanding everywhere at once without an absolute center within itself also means it can't have linear dimensions.

In general, linear coordinates work well for small, fixed spaces but not for a huge space like ours, that is expanding indefinitely from no point within itself.

2.2.4. Is space scalable?

A scalable system is one whose performance doesn't degrade as it expands, however big it gets (Berners-Lee, 2000). As a network grows, it gets more demands but if growth increases supply as well as demand, its performance doesn't degrade. A network is scalable if each new point added increases supply as well as demand. The Internet was designed this way, as each new Internet Service Provider adds more processing to handle demands as well as more users to create demands.

One way to make a network scalable is to decentralize control by giving each point its own processing, so each new point adds processing power as well as load. When the Internet began, pundits expected it to collapse in chaos without central control, but instead it thrived. It was then realized that centralized networks collapse suddenly when stressed because an overload crashes the whole system, but decentralized networks degrade gracefully because an overload gives a local crash but the rest carry on. We think dictatorships are strong but nature knows they aren't, so scientists expected brains to have a control center but they don't, because decentralized networks are more reliable (Whitworth, 2008).

Is our space then scalable? The evidence suggests so because the laws of physics didn't change as space expanded (Sutter, 2022). Space today behaves as it did when our universe was the size of a golf ball, so it is scalable. It follows that new points of space add processing to allow it to expand indefinitely. Each point of space then has a finite ability to process matter, and the evidence agrees:

> "*...recent observations favor cosmological models in which there are fundamental upper bounds on both the information content and information processing rate*." (Davies, 2004), p13.

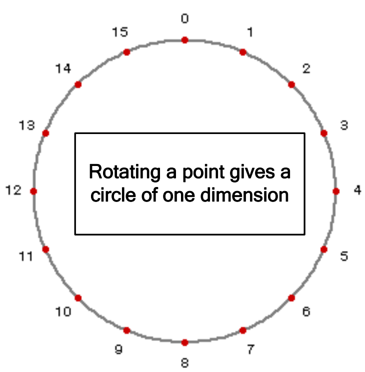


Figure 2.3. A circle circumference has one dimension

We call the upper limit of what space can hold a black hole, so that black holes exist also suggests that our space is scalable.

2.2.5. A polar space

To reverse engineer space, its properties must be known. If space is nothing at all, as Leibniz thought, it has no properties, but nothing at all can't expand as our space does. If space is something, it must have properties, which by the previous sections, are that it is:

- *Discrete.* Made of points with a minimum size.
- *Directional.* Its points allow finite directions of movement.
- *Three dimensional.* It has three degrees of movement freedom.
- *Finite.* It isn't infinitely large in size.
- *Expanding everywhere.* It isn't expanding from an origin point within itself.
- *Scalable.* Doesn't change as it expands, as far as we can tell.

Our space can't be Cartesian because it isn't expanding from a point within itself, yet linear space is so deeply ingrained in western thought that some think it is the only way a space can be, but it isn't. Euclid derived his coordinates by extending a point in a straight line, then extending another line at right angles to get a plane, then repeating to get a volume, but mathematics also lets us extend a point by rotations, to derive polar coordinates[3].

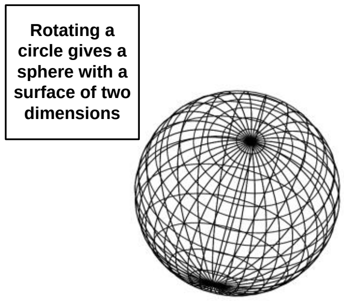


Figure 2.4. A sphere surface has two dimensions

A polar space also begins with a point, as before, but this time it needs extension to stand alone, as a point of no extent can't exist. The first dimension then arises from a rotation around that point, to give a circle, whose circumference represents a dimension of points (Figure 2.3). This dimension has two directions, as each point connects to two neighbors. The distance between points is the number of connections between them, so points 1 and 2 in the figure are close, but points 1 and 10 are far apart. The circle is also finite, and it can expand indefinitely from a point that isn't on itself (the circle center).

Then, just as Euclid extended a line, a circle can extend by orthogonal rotation to give a sphere whose surface has two dimensions (Figure 2.4). Again, as the sphere expands, its surface increase everywhere at once, not from a point on itself. This matches how cosmologists say our space expands, which is like a ballon surface, for as Hoyle said:

> *"My non-mathematical friends often tell me that they find it difficult to picture this expansion. Short of using a lot of mathematics I cannot do better than use the analogy of a balloon with a large number of dots marked on its surface. If the balloon is blown up the distances between the dots increase in the same way as the distances between the galaxies."* (Hoyle, 1950).

Our space expands everywhere at once, like the surface of a balloon being blown up, so a two dimensional being living on such a surface would see a space that is discrete, directional, finite, and increasing everywhere, just like our space, but with two dimensions instead of three. To a reverse engineer, this suggests that our space is polar not linear, but is a three-dimensional polar space possible?

2.2.6. Three polar dimensions

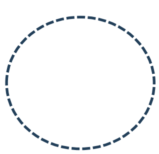
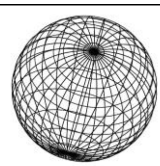
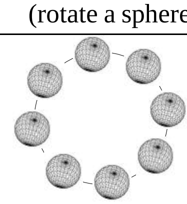
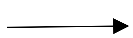
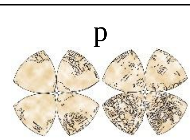
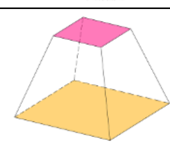
	Circle (rotate a point)	**Sphere** (rotate a circle)	**Hyper-sphere** (rotate a sphere)
Shape			
Surface	 *1 Dimension*	 *2 Dimensions*	 *3 Dimensions*

Figure 2.5. A hypersphere surface has three dimensions

Euclid extended a point three times to get three linear dimensions, so would three orthogonal rotations around a point give three polar dimensions? It would, but after the first two rotations give a circle and a sphere, our space has no more dimensions to rotate into. Yet in mathematics, rotating a sphere in an orthogonal direction gives a hypersphere. A hypersphere is a sphere rotated in another dimension as a sphere is a circle rotated in another dimension, so its surface has three dimensions (Figure 2.5).

The possibility that our space is a surface was introduced by Bernard Riemann in 1857, as his Riemann Sphere is a hypersphere whose surface has three dimensions, just like

[3] Cartesian coordinates are represented by (x, y, z) values, but polar coordinates are represented by (r, α, β), where r is the radius from a fixed point, and alpha and beta are angular directions. Both systems need a (0,0,0) point.

our space. It still applies today because relativity lets space curve like a surface and cosmology lets it expand like a surface. It follows that our space could be a three-dimensional surface within a four-dimensional bulk:

> "*When it comes to the visible universe the situation could be subtle. The three-dimensional volume of space might be the surface area of a four dimensional volume*" (Barrow, 2007), p180.

Davies makes the case even more clearly:

> *"… the shape of space resembles a three-dimensional version of the surface of a sphere, which is called a hypersphere.*" (Davies, 2006), p45.

The mathematics is solid, but a hypersphere needs a fourth dimension outside physical space. Our space doesn't have four degrees of freedom but the network generating it could have. Just as a three-dimensional network can represent a circle and a sphere, so a four-dimensional network can represent a hypersphere. Our space would then be a three-dimensional surface, just as computer screens are two-dimensional surfaces. Our space behaves like a hypersphere surface so if it is generated, it could actually be so. A four-dimensional quantum network could create a three-dimensional surface that acts like our space, based on polar dimensions. Reverse engineering then suggests that our space is the surface of hyper-bubble expanding in the quantum bulk.

This conclusion explains why our space is expanding everywhere at once, not from a physical centre, as a linear space would. It also implies that our space is curved. Planets, stars, and galaxies are curved, so why not the universe? The earth was once thought flat because it seemed so, but now we know it isn't, so is space the same? But if space is curved, why does it seem flat to us? One answer is that a hypersphere surface that has expanded for 14 billion years at the speed of light would seem flat to us, just as the surface of the earth once did. What else then does space as a hypersphere surface imply?

2.2.7. Space has gaps

In the derivation of polar space, the number of steps in each rotation is finite, so it is a discrete rotation. A discrete rotation must have a finite number of steps, so a triangle is made by three rotation steps, a square by four, a pentagon by five, and so on (Figure 2.6), where these N-rotations approximate a perfect circle as N increases. More rotation steps seem better because they allow more interaction directions, but wargamers use hexagons not octagons because a board of octagons has gaps in it. Hexagons fill the surface completely but octagons don't, so the former are preferred.

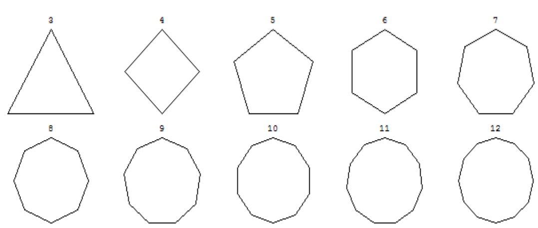


Figure 2.6. N-rotations, N = 3-12

In general, a rotational space based on a large N, as expected here, will have gaps in it, so not all paths will be reversible. Taking a route in reverse might not return to the exact same point, though it would be a true vicinity. A polar space with holes in it would allow particles to pass right through each other! Does this property then exclude a discrete polar space from describing our space?

It might seem so, but quantum theory describes quantum entities as probability clouds not billiard ball particles. When these clouds collide, they overlap an area, so a space with a few holes in it doesn't matter. If quantum entities are probability clouds, a polar space with gaps in it still works.

For a polar space, the circle of neighbors around a point will be a finite number N, so it will have that many transfer connections. If each connection is a direction, this predicts that a point in space has a finite number of directions, so direction, like length, will be quantized as a minimum Planck angle[4]. Experiments with high frequency light could test whether quantum events have a minimum Planck angle.

[4] If a point has N neighbors in a circle around it, the minimum Planck event angle is 360°/N.

2.2.8. Space is contained

If our space is a surface, it must be contained within a larger space. This idea arose in physics over a century ago, when in 1919, Kaluza derived Maxwell's equations from Einstein's equations given another dimension. He essentially unified quantum theory and relativity, but another physical dimension was impossible because another it would make gravity vary as an inverse cube, so the solar system would collapse. Physical realism required any other dimension to be physical, so Kaluza's promising discovery was ignored. Bearing this in mind, when mathematicians later discovered that light could be explained by a rotation into a fourth dimension, they were careful to call it imaginary, so complex numbers were accepted.

Klein then tried to rescue Kaluza's extra dimension by suggesting that it was curled up in a tiny circle that went nowhere, so it existed but did nothing, but this was also ignored. Years later, string theory resurrected his idea to explain its extra dimensions, but couldn't explain why nature has extra dimensions that do nothing but make our equations work.

But if physical space is itself a surface, these confusions disappear. Instead of an extra dimension inside space, there is a dimension outside space by which it is observed. Just as a two-dimensional screen needs a third dimension to be seen from, so our space needs a fourth dimension to be seen from. Hence, some physicists now suggest that our world is a "slice" of a higher-dimensional world:

> "*Physicists have now returned to the idea that the three-dimensional world that surrounds us could be a three-dimensional slice of a higher dimensional world.*" (Randall, 2005), p52.

They note that this extra dimension is sequestered from our space, so it doesn't alter gravity or charge (Randall & Sundrum, 1999). If there was another physical dimension, we could walk out of this world, but we can't, any more than an avatar can leave a game screen. We are contained by space, like goldfish in a bowl, so for us it is the ultimate container, but space as a surface means that it is also contained within something else.

2.2.9. Space vibrates

Light travels in empty space but how can a transverse wave do that? Sound is also a wave, but there is no sound in empty space because there is nothing to transmit it. Yet light from the sun and stars still reaches us across the emptiness of space, so how can a wave do that without a medium?

Consider a wave travelling across a pool surface. The wave moves because the water moves, but a cork floating on the pool just bobs up and down as waves pass it. The waves don't push the cork along because the water doesn't move in the wave direction, it moves up and down. What moves as a wave isn't the water, but it's up-down surface displacement, so when a pebble drops on a still pool, that displacement spreads as waves. Waves spread when a surface vibrates up and down, so shouldn't light be the same?

A transverse wave is one that vibrates at right angles to its movement direction. Water waves are transverse waves because the water moves up and down as the wave spreads horizontally. Light is also a transverse wave even though it moves in three dimensions not two. It is said to have no medium because materialism calls empty space nothing, but if space is a surface, then light could vibrate *on space*.

The theory of relativity agrees that our space is a surface because it lets space curve, and complex number theory adds that light vibrates in a dimension outside space. If these theories are correct, then the surface of space can host light as a transverse wave. Light travels in a vacuum, so it either vibrates nothing at all, which denies how waves work, or it vibrates something. The simplest option is that light is a vibration on the surface of space itself.

Why then don't we see light waves moving up and down, as water waves do? We know that light vibrates, but a ray of light seen from the side doesn't seem to move up or down. This is expected if the dimension into which light vibrates is sequestered from our space (Randall, 2005). Everything we see is based on light but a transverse wave can't leave the surface it vibrates on, so we can't use it to see what happens outside space. It takes reverse engineering to deduce that light vibrates on space.

But what exactly moves when light moves? According to physical realism, nothing can, but the alternative explored here is that the quantum network does. Maxwell's equations describe light as an electromagnetic vibration orthogonal to space. Let this vibration be the quantum network setting a transverse circle of positive and negative displacements on the surface of space. If they complete at the same point in a cycle, it is a null process, or empty space, but the same process distributed over two or more points can be a wave of light (Figure 2.7). Chapter 3 gives more details, but essentially light is a positive-negative surface displacement, just as water waves are. What moves when light moves is then what we call quantum processing.

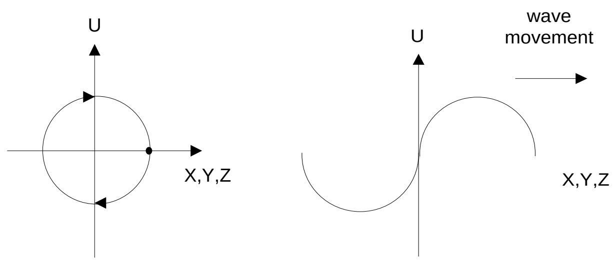


Figure 2.7. A transverse circle can be space or light

Quantum waves spread on the quantum network, and light is their simplest form, but what actually are they? Schrödinger called them matter density waves, because they predict where matter exists, but quantum waves aren't made of matter. Born called them probability waves, because their amplitude squared at a point is the probability that matter exists there, but a probability is just a number. We expected the ultimate reality to be made of matter, but instead have found just waves. The quantum waves that predict physical events have no mass, momentum, velocity, or any other physical property, but they can manifest as space, light, and matter, as will be seen.

2.2.10. Space transmits

Objects tend to move in a straight line, defined as the shortest distance between two points. The general term is geodesic because on a curved surface like the earth, the shortest distance between the poles is a curved longitude. A geodesic is a straight line on a curved surface, but why do objects move in straight lines in the first place?

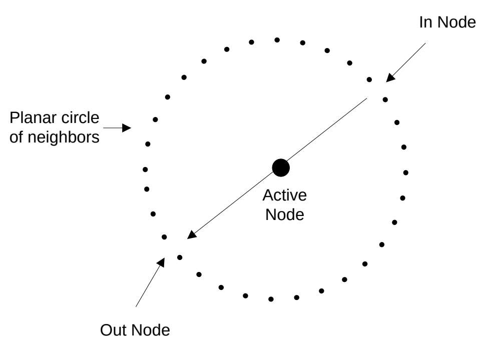


Figure 2.8. A planar circle transfer

Billiard balls on a table are said to move in straight lines by a property of matter called inertia, the tendency to continue in the same direction. Inertia then makes an arrow shot into the air fly up. But then it falls to the ground, so Newton suggested that a force from the earth pulled it down, called gravity. The arrow then moved according to the forces of inertia plus gravity, with space just a passive context. In classical physics, inertia makes objects move in straight lines unless another force is acting. It followed that inertia and gravity, both properties of matter, determined how objects move.

Einstein then showed that gravity works by curving space, to alter the geodesic, so an arrow fired into the air actually still moves in a straight line. We see a curve because space itself is curving, just as a globe longitude is curved but still the shortest distance between the poles. If the earth curves space around it to cause gravity, the moon then orbits the earth because that is its straight line. This changes the logic, as now gravity isn't a force acting on an object, but a change in space that alters what a straight line is. It follows that inertia could also be a property of space, not the object itself.

How a wave moves on a network depends on how it is passed on, so if space is a network that transmits waves, light moves in a straight line because that is how it is passed on. Light then moves in a straight line because of space, and continues to do so unless something alters space. To understand how this could be, suppose that:

> "*A point in spacetime is … represented by the set of light rays that passes through it.*" (S. Hawking & Penrose, 1996), p110.

If these rays represent the connections of a point to its neighbors, its possible transfer directions are a sphere around it. But if a photon is a transverse wave, it can only move at right angles to its vibration direction, so its directions are a circle not a sphere. Hence, every photon has a polarization plane at right angles to its vibration that limits how it moves through a point to a planar circle (Figure 2.8), as it must enter from and exit to points on that circle. Planar circles simplify how photons are passed on by a point, just as planar anyons simplify the quantum Hall effect (Collins, 2006).

Why then does light move in straight lines? For a network, the shortest path between any two points is the one with the fewest transfers, which is also the fastest path. For a wave spreading in every direction, the fastest path to any point is a straight line. Light will then move in a straight line to any point if it always takes the fastest route, which it does.

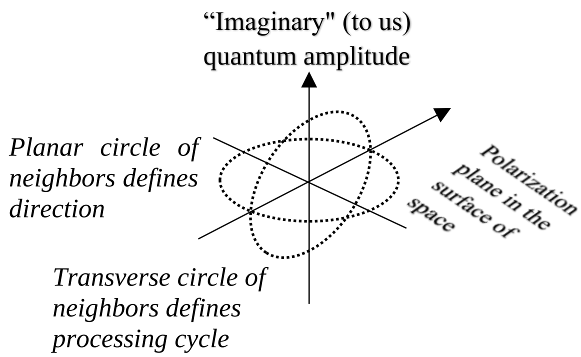


Figure 2.9. Planar and transverse circles

Chapter 3 gives the details, but essentially light travels in a straight line because its waves take every path to a destination and the first to arrive triggers a physical event. It follows that light moves in a straight line by a property of space, not itself. Chapter 4 extends this conclusion to matter objects, and Chapter 5 explains how gravity alters space, as Einstein said. The classical view that things move by their own inclination within a space of nothing is thus replaced by the view that they move according to how the network of space passes them on.

In conclusion, a quantum network can generate a space like ours based on rotations. The resulting polar space explains how space expands, how objects move, and how light vibrates, better than the linear space of Euclid. If the geometry of the universe is based on circles not squares, then for a point, planar circles specify how light is passed on and transverse circles specify how it vibrates (Figure 2.9). In the next section, transverse circles define time, just as planar circles define space.

2.3. CREATING TIME

Time is something we all understand until we try to explain it to another who doesn't. As Saint Augustine wrote over eight centuries ago:

> *"What is time then? If nobody asks me, I know; but if I were desirous to explain it to one that should ask me, plainly I do not know."* (Chadwick, 2008).

Today, time is still in many ways a mystery. Some physicists say that is a dimension, but why then can't we move back and forward along it, as we do for the dimensions of space? Others say that time itself can change, to flow slower or faster, but what does it change with respect to? Surely not itself, as that seems illogical. This section addresses such questions by reverse engineering time.

2.3.1. Time dilates

If objects in our world exist constantly, by themselves alone, their time should pass absolutely, at a fixed rate regardless of events. In contrast, if objects in our world are virtual, their time will pass as their pixels are generated, so if we pause a game, the screen freezes and time in that game stops, until it is restarted again. In a game world, time passes as game events occur.

For example, Conway's Game of Life produces pixel patterns that arise, change, and vanish, to simulate how living things arise, change, and die in our world (Figure 2.10). If we pause the game, its time stops, and if we restart it, its time carries on. The lifetime of a pattern is then the number of game events that it exists for. Time in a virtual world is measured by its events just as we measure our time by atomic events.

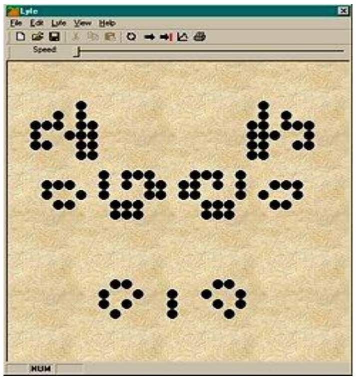


Figure 2.10. Conway's Life

Now suppose that a pixel pattern repeats for twenty minutes of our time, is that its lifetime? It might seem so, but if the game runs on a faster computer, that pattern might only repeat for a few seconds. To us, it lives less, but the number of computer events is the same. The lifetime of a game entity doesn't change when it runs on a faster computer, because the events completed are the same. The same pattern run by two computers, one fast and one slow, has the same game life, even though we see different times.

This can explain Einstein's twin example. Relativity predicts that a twin who travels in a high-speed rocket for a year could return to find his brother is an old man of eighty. Neither twin would know that their time ran differently, but one twin's life could be nearly over while the other's is still beginning. Yet the eighty-year-old twin wouldn't be cheated, as he still got eighty years of heart beats, and grandchildren to boot. The twins would only realize that their time had passed differently when they met again, to find themselves at different ages. Relativity predicts that our lifetimes can change just as lifetimes change in Conway's Life, so our time can change as it does in a game world!

When people first hear that our time changes, they think it is a trick, that only perceived time changes, but it isn't so, because it is the time measured by clocks that changes. For example, accelerating short-lived particles can double their observed lifetimes. Speed shouldn't change how time passes in an objective world, so why does it change how time passes in our world?

To understand this, consider a computer game where events occur on the screen one after another. In a big battle, when a lot of events occur quickly, gamers expect the screen to slow down when the computer has a lot to do, because drawing more events on the screen takes longer. The battle event sequence stays the same, but the screen lags when more events occur.

This suggests that time slows down when objects go faster in our world because the quantum network has more to do. Each point of the quantum network has a finite capacity, so it can only generate life events at a certain rate. If movement also uses that capacity, increasing the rate of movement will decrease the rate of life events, giving a trade-off between an entity's lifetime and its speed. If an object goes faster, its life will run slower to compensate, so its time slows down.

Just as a game slows down when there is more to do, so our lives slow down when we move faster. In Einstein's example, the rocket twin's life ran slower because the quantum network had to manage his movement as well, so he only aged a year, but his earth twin had no such load, so eighty years of life passed in the usual way. In our world, going faster makes life go slower, as it dilates time, but does this make time travel possible?

2.3.2. Time Travel

An object that constantly exists in space has left and right parts so if it constantly exists in time, it could also have past and future parts. Minkowski interpreted Einstein's relativity to be that objects exist in a spacetime matrix at (x, y, z, **t**) points where **t** is time, and so travel along four-dimensional world lines in space and time. This allows a block theory of time, where the present is just a slice of a larger block of past and future events, giving a time capsule that could be browsed like the pages of a book (Barbour, 1999), p31. If matter exists on the landscape of time, then time travel is indeed possible because the past and the future exist right now.

The equations of relativity allow time travel, but that doesn't make it so, because equations aren't theories. For example, the equations of movement assume that all of an object's mass exists at its center of gravity, but it isn't actually so. It follows that when physicists say time travel is based on general relativity, they mean it is based on Minkowski's interpretation of it, which is a mathematical model not a theory.

Actually, no physical evidence at all supports time travel, and assuming it is so creates unsolvable paradoxes. For example, Minkowski's interpretation allows closed time-like curves, where an object's world line returns it to its start point just as an object can return to where it was in space, but this means it can collide with itself! A block theory of time allows the following paradoxes:

a. *The grandfather paradox:* A man travels back in time to kill his grandfather, but then couldn't be born, so he couldn't kill him. Backward time travel lets an entity prevent its own cause, so causality breaks down. It follows that there can be going back in time or causality, but not both.

b. *The toast paradox:* I go forward in time to see myself having toast for breakfast, then return, but next morning I decide not to, so I didn't go forward in time. Forward time travel assumes a fixed future so it denies future choices. If life is a movie already made, the future is predefined, so random events can't occur, but they do. It follows that there can be going forward in time or choice, but not both.

Going back in time denies causality, and going forward in time denies choice, but physics requires both. Without causality, it must allow magic, but it doesn't, and without choice, it must deny randomness, but it doesn't. Physics rejected Newton's idea that reality is painted upon the canvas of space, and making that canvas spacetime doesn't improve this. After all, if we ever learn to travel in time, wouldn't we immediately go back in time to fix past errors? Like the multiverse fantasy, time travel is great science fiction but poor science. It follows that if physics accepts causality and choice, it must deny time travel.

2.3.3. Specifying time

That time, the measure of all change, can itself change defies logic, but Einstein showed that time can dilate, so how can the measure of change itself be changed? In calculus, a change in time is dt/dt, which is a constant, so time itself shouldn't change. That it actually does has led some to conclude that time and space aren't as fundamental as Newton thought:

"*… many of today's leading physicists suspect that space and time, although pervasive, may not be truly fundamental.*" (Greene, 2004), p471.

If time isn't fundamental, it could be generated, which could explain how it changes. This allows us to reverse engineer time, but to do so, we must specify its nature. In traditional thought, time is:

"… a sort of river of passing events, and strong is its current; no sooner is a thing brought to sight than it is swept by and another takes its place, and this too will be swept away." M. Aurelius, Meditations, Book IV, p43.

If time is like a river of events, those events specify time, so a time like ours requires events that are:

1. *Sequential*. Events occur one after another.
2. *Lawful*. Current events are based on past events.
3. *Indeterminate.* Future events vary in unpredictable ways.
4. *Irreversible.* Events that have occurred can't be undone[5].

That time is like a river requires physical events to be sequential, lawful, indeterminate, and irreversible, so the quantum events that generate them must be the same. If quantum events aren't sequential, the physical events they generate won't be either. If quantum events aren't lawful, the physical events they generate won't be either. If quantum events aren't indeterminate, the physical events they generate won't be either. If quantum events aren't irreversible, the physical events they generate won't be either. To create a time like ours, quantum events must be sequential, lawful, indeterminate, and irreversible, but are they? Quantum theory gives the answers.

1. Sequential

Events are sequential if one event follows another, like a river flowing, and quantum theory tells us that quantum waves:

[5] The special case of anti-matter generating anti-time is explained in Chapter 4.

"*... evolve to a finite number of possible successor states*" (Kauffman & Smolin, 1997), p1.

If one quantum event follows the next, in succession, they must be finite. In an infinite sequence, one event can't follow another because there are always other events between them. In quantum theory, each event is a discrete step, so they follow each other sequentially. If quantum events are sequential, they can generate a time that is sequential, like ours.

2. Lawful

Events are lawful if current events are based on past events, like a river flowing, and quantum theory tells us that quantum events evolve lawfully. Quantum waves spread, overlap, and collapse to physical events only as quantum laws permit, so physical laws can arise from quantum laws. If quantum events operate lawfully, they can generate a time that flows lawfully, like ours.

3. Indeterminate

Events are indeterminate if they can't be perfectly predicted from past events, like a river flowing, and quantum theory tells us that physical events are choices. A choice, by definition, has a known before but an unknown after as before the choice, the options are known but the choice result isn't. If the result of a choice is known beforehand, then it isn't a choice, so a choice is an indeterminate event. In quantum theory, a photon wave approaches a screen then collapses at a point chosen from the possibilities, in a physical event. No physical history can explain where the photon will hit the screen, so it is a choice. Quantum theory adds that every physical event includes such a choice, so if our world is a quantum machine, it is one with:

"*...roulettes for wheels and dice for gears.*" (Walker, 2000), p87.

Where and when quantum collapse occurs is random because no physical history can explain it, but the resulting physical event still has a lawful history. If quantum events choose physical events, they can generate a time that is indeterminate, like ours.

4. Irreversible

Events are irreversible if they can't be undone, like a river flowing, and quantum theory tells us that quantum collapse is irreversible. All the equations of physics are time reversible, so reversing time doesn't break any physical laws, so why isn't our time reversible? Quantum theory doesn't say why quantum collapse can't be undone, but if quantum waves are processing waves, it could be because a collapse is a reboot.

When you turn your phone off, then on again, it reboots. It restarts everything from scratch, so any work in progress is lost, unless you saved it. Normal phone events are a sequence so they can be undone, but a reboot can't be undone because it wipes the slate clean, to start a new sequence. The events before a reboot are gone forever, so it can't be reversed, just as when quantum waves collapse, the previous wave disappears instantly, so there is no past to revert to. This suggests that quantum collapse is a reboot. If quantum collapse is a quantum wave reboot, it can generate a time that is irreversible, like ours.

In conclusion, if quantum waves spread on the network until a point overloads and reboots in a physical event, quantum reality could generate a time that is sequential, lawful, indeterminate, and irreversible, just like ours. Such a time implies a physis of now.

2.3.4. A Physics of now

A movie can fast forward to future events or flashback to past events, so if our world is virtual, can it do that? It could, but reverse engineering isn't about speculating what could be but explaining what is. In this case, that quantum events generate time explains how it slows down, but no evidence requires a past or future to exist now. This gives what philosophers call presentism, that only the present exists, so to worry about the past or future is to worry about what is imaginary. We deduce that time extends, but only know the past from the present and the future is uncertain, so a time like ours only requires the now and we infer the rest. A constantly active quantum network can create the present but beyond that, it can't store what it does because it is too busy doing it (2.1.4).

The quantum network can't record what it does but, in a way, the physical world does just that. Observing a physical event is like querying a database to get the latest update, as it is essentially a report on myriad quantum events. This report can reflect the past, as brain memories today can recall yesterday's events, and dinosaur fossils today reveal can what happened long ago. Our DNA stores not only the choices of our ancestors, but of all life on earth. Genes (Dawkins, 1989), norms (Whitworth & deMoor, 2003), and memes (Heylighen, Francis & Chielens, K., 2009) record past biological, cultural, and ideological choices, so physical events record quantum history.

How then did the quantum network begin space and time? Physicists propose that our universe began with four equal dimensions, until the first event turned one into time and the rest into space, to break that symmetry (S. W. Hawking & Hartle, 1983). But what were those initial dimensions? Physics has no abstract property that can turn into space or time but a network does.

The connections of a network can represent two spatial dimensions in a plane, and connect a cube to represent three, so with enough connections, it can represent four dimensions. A quantum network with four degrees of connection allows four equivalent dimensions, any of which can become space or time. If our space is based on three orthogonal rotations, and our time on another rotation, Hawking and Hartle may be correct. Reverse engineering allows equivalent quantum connections to generate the dimensions of our space and time.

It follows that our world has no absolute time, only network cycles that imply time, and it has no absolute space, only network transfers that imply space. Time passes as light completes cycles to reach us, and distance extends as it completes transfers to reach us. Time and space are then outcomes not causes, so space can contract and time can dilate, as relativity experiments confirm.

We deduce a dimension of time but all we know for sure is the present. The quantum network creates the here and now and we do the rest. Physical presentism is not only that we should live in the present, but also that we should theorize in it, because nothing else really exists. It implies a *Physics of Now* (Hartle, 2005), p101, where only the present exists. We can predict the future and deduce the past, but only based on the present. Likewise, only events here let us deduce galaxies that would take a million years to reach. When we abandon the idea that reality is a space-time block, all that remains is the ever-present here and the eternal now.

2.4. IMPLICATIONS

That the time and space we see all events within are generated has implications for physics. Instead of space being the ultimate container, it is itself contained. Instead of our universe beginning with a big bang, it began as a little rip. Instead of space being empty, it is full. But the quantum network needs a protocol to work reliably, just as our networks do.

2.4.1. Space is a surface

In 1929, the astronomer Hubble observed that all the stars and galaxies were speeding away from us, so our universe is expanding everywhere. But if so, why is light from just after the big bang still all around us today, as cosmic microwave background? If the early light exploded outwards, shouldn't it be at the edge of the universe not here? Current physics doesn't explain this, but space as an expanding surface does (2.2.5).

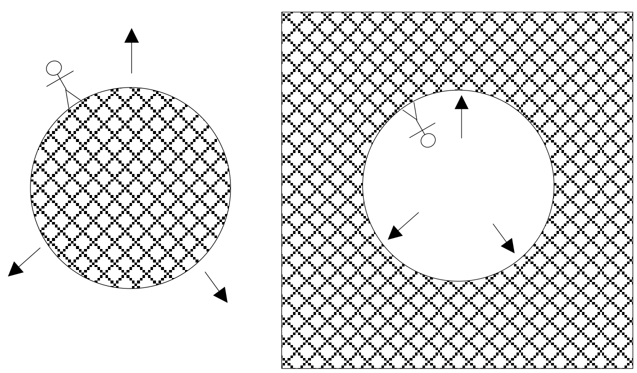


Figure 2.11. Big bang vs. big bubble

A hypersphere surface has three dimensions like our space and no edges like a balloon surface, so it lets our space expand everywhere at once, not just at an edge. Yet while a balloon expanding thins out, our space hasn't changed in billions of years. This suggests that we are on the *inside* surface of expanding bubble, not the *outside* of a stand-alone balloon (Figure 2.11). The surface of a bubble in a liquid doesn't thin out as it expands because its surface comes from the liquid, not itself. It still has no center or edge, so any waves on it will wrap around to end up everywhere. Hence, light from long ago is still all around us, as cosmic microwave radiation. It also answers questions like:

1. *What is space expanding into?* It is expanding into the bulk around it.
2. *Does space end?* No, a bubble surface has no end.
3. *Where is space expanding?* Everywhere, just as a bubble surface expands everywhere at once.
4. *How does new space arise?* As the bubble expands, new space comes from the bulk around it.
5. *Are we expanding too?* No, objects on a bubble surface don't expand as the bubble does.

Space as an expanding bubble surface is homogenous but not continuous, expanding but not exploding, never-ending but not infinite, and curved not flat. Instead of hosting particles *in* space, it only hosts waves *on* space, so our universe is built from waves not particles.

2.4.2. The little rip

Based on how fast our universe is expanding, scientists were able to rewind back to when it began. Big bang theory is that about 14 billion years ago our entire universe existed at a point that exploded out to become what we see today, but for this to be true, several miracles had to happen.

The first was that everything in our universe had to come from nothing. It is a miracle because from nothing, nothing comes, so how can a universe come from it? This is the *something from nothing miracle*.

The second miracle was that our entire universe initially existed at a point, called a singularity. It is a miracle because by the laws of physics, matter at that density should immediately collapse into a black hole, from which even light can't emerge, so the universe would be stillborn. This is the *singularity miracle*.

To avoid this, Guth proposed inflation theory (Guth, 1998), that an immense anti-gravity field expanded the singularity faster than light for 10^{-32} seconds, so it didn't become a black hole. He solved one miracle by proposing another, because according to relativity, nothing can move faster than light. This is the *faster than light miracle*.

This huge field then vanished as suddenly as it appeared, for no reason, to play no further part in our universe. It is a miracle because no other fields of physics have ever vanished. This is the *vanishing field miracle*.

Instead of an all-powerful being creating the universe, physics now says that it came from nothing, to exist at a single point, that a massive field expanded faster than light, until that field vanished forever, leaving the universe to slowly evolve into galaxies, stars, and us. But how is trading one miracle for four an improvement, despite its scientific veneer? Is there any theory that avoids these miracles.

Quantum realism begins by stating that quantum waves exist, based on the evidence. A universe that began must begin from something, so the network that hosts those waves could have existed before our universe began, to start it. But how can one reality give rise to what isn't itself? One way, for a network, is to create a virtual reality based on server-client relations.

A server-client relation is when one point of a network tells another what to do. For example, if I print this page, my laptop tells the printer what to print, so it is a server and the printer is a client. If a client job fails, the server can restart it so my laptop can resend the page if the print fails. Likewise, if a quantum wave is client events spreading on a network, it can restart again as quantum theory says. A server directing a quantum wave can restart it if it fails just as I can restart a print that fails. That the physical world began as server-client waves then avoids the something from nothing miracle.

Our universe as a server-client virtual reality should begin as our software environments do. When a Windows computer is turned on, it first loads a tiny CMOS program, that then loads a kernel program, that loads a bigger BIOS, that loads the full Windows environment, so the software starts in a step-wise manner, not all-at-once. If our universe did the same, the first event only needs to create one photon to start it off. That our universe began as one photon then avoids the singularity miracle, because one photon won't collapse into a black hole.

To create a photon, which is one quantum wave, only requires one network point to give its activity to its neighbors, to became a server. Doing this would leave a Planck size hole in the network, so space also began when our universe did. This white-hot speck of light could then trigger other points to do the same, just as a little rip in a taught fabric quickly becomes big. Inflation was then the quantum fabric dividing itself into servers and clients, to give an initial plasma that was:

"… essentially inhabited by massless entities, perhaps largely photons." (Penrose, 2010), p176.

In our networks, server events are faster than client events because directing an event is faster than doing it. Hence, if the initial creation of photons was a server chain-reaction, it would occur faster than the speed of light, which reflects the client rate of network transfer. That inflation was a server chain-reaction then avoids the faster-than-light miracle, but why didn't it continue forever?

In the above, each step of the inflation chain-reaction produced both light and space. Adding space extended the wavelength of light to dilute its energy, so light that was white-hot at the dawn of time is now cold. The generation of light was exponential, as light begat light, but the hypersphere surface of space grew as a cubic function, which overpowers exponential growth if the resolution is quick (Figure 2.12), as physics says it was[6]. That space expanding stopped inflation by cooling the light causing it then avoids the vanishing field miracle.

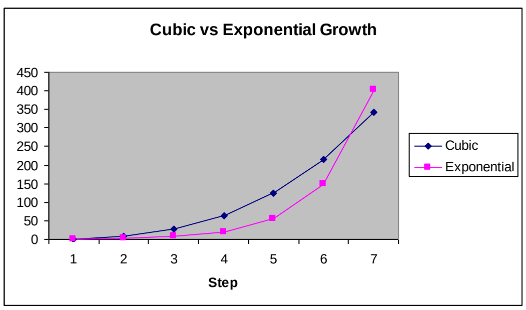


Figure 2.12. Cubic vs. exponential growth.

It follows that the big bang wasn't big, at first anyway, nor was it a bang, as initially there was no space to explode into. It was a little rip in the primal reality that made both light and space. The quantum network separated itself into servers and clients to create the quantum waves that cause physical events, so our universe was borne not manufactured. Space expanding then healed the rip, but not before all the photons in our universe had been created. In this view, our universe began as nothing but white-hot light, and matter came later, as Chapter 4 explains. After the initial act of creation, space continued to expand, cooling the universe down, so space expanding isn't just an oddity of physics. We only exist because it cooled the universe enough to accommodate us.

In conclusion, our universe came from something not nothing, it was a little rip not a big bang, followed by an outward push not a pull, that was stopped by the expansion of space not a field disappearing. No miracles are needed, given only that quantum waves exist.

2.4.3. Transfer errors

Our networks need protocols to avoid transfer errors, so how does the quantum network handle this? Transfer errors are when network data is sent but not received, like when a catcher drops a ball from a pitcher. For example, if one point sends data to another when it is busy, the transfer is lost, just as a ball thrown when the catcher isn't ready is dropped. Equally, if two points transfer to the same point at the same time, one is lost, just as if two pitchers throw two balls to a catcher at the same time, catching one means the other is lost.

But does it matter if a transfer is lost, as after all, it's just information? Unfortunately, the money in your bank account is also just information, so a failed bank transfer could lose it all! If two people call you at once, it may not matter that one gets a busy signal, but on a network, losing a transfer loses what it represents. In a virtual world like Sim City, objects are represented by information, so a failed transfer could make the sword in your hand suddenly disappear, so networks can't afford to lose transfers.

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[6] In inflation theory, an immensely strong anti-gravity field pulled the entire physical universe from the size of a proton to the size of a baseball faster than the speed of light, then 10^{-32} of a second later that field conveniently disappeared forever.

Our universe has, as far as we know, conserved energy for billions of years, so if the movement of every photon in our universe is a transfer, none have been lost, or we would notice it. If our world is virtual, the network generating it must avoid transfer errors, but how? Our networks avoid transfer errors by protocols like:

1. *Locking*. Makes a receiver exclusively available before sending the transfer.
2. *Synchrony*. Synchronizes all transfers to a common clock.
3. *Buffers*. Stores transfer overloads in a buffer memory.

Could a quantum network use any of these methods?

Locking. Locking makes a receiver dedicate itself to a sender before the transfer is sent. For example, if I edit this document, my laptop locks it exclusively, so any other edit attempt fails, with a message that it is in use. Otherwise, if the same document is edited twice, the last save will overwrite the changes of the first, which are lost. Locking avoids this by making every transfer two steps not one, but also allows transfer deadlock (Figure 2.13), where point A is waiting to confirm a lock from B, that is waiting for a lock from C, that is waiting for a lock from A, so they all wait forever. If the quantum network used locking, we would occasionally find dead areas of space unavailable for use, but we never have, so it can't use locking to avoid transfer losses.

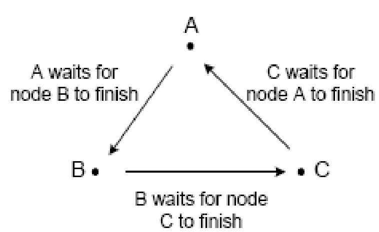

Figure 2.13. Transfer deadlock

Synchrony. On a computer motherboard, when a fast central processing unit (CPU) sends data to a slower memory register, it must wait before sending another transfer. If it sends data again too soon, the transfer fails because the register is still busy with the first transfer. On the other hand, if it waits too long, this wastes valuable CPU cycles. It can't check if the memory is free before sending because that is a new command that also needs checking! Using the double-send of locking would slow the motherboard down, so it uses a common clock to synchronize events. The CPU sends data to memory when the clock ticks, then sends more data when it ticks again. This avoids transfer losses if the clock is set to the speed of the slowest component, plus some slack. One can increase a motherboard's clock rate, to make it run faster, but too much over-clocking will crash it. Synchrony requires a common time but according to relativity, our universe doesn't have that. If the quantum network had a central clock, it would cycle at the rate of its slowest part, say a black hole, which is massively inefficient, so it can't use synchrony to avoid transfer losses either.

Buffers. The Internet uses memory buffers to avoid transfer errors so it can be decentralized. Protocols like Ethernet[7] distribute control, to let each point run at its own rate, and buffers handle the overloads. If a point is busy when a transfer arrives, a buffer stores it to be processed later. Buffers let fast devices work with slow ones. If a laptop sends a document to a printer, it goes to a buffer that feeds the printer in slow time, so you can carry on working while the document prints. But buffers require planning, as too big buffers waste memory and too small buffers can overload. Internet buffers are matched to load, so backbone servers like New York have big buffers, but backwaters like New Zealand have small ones. In our universe, a star is like a big city while empty space is a backwater. If the quantum network used buffers, where stars occur would have to be predictable, which according to quantum theory, wasn't so. Equally, same buffers in the vastness of space would be a massive waste of memory, so it can't use buffers to avoid transfer losses either.

Our networks avoid transfer losses by locking, synchrony, or buffers, but quantum events proceed one step at a time so the quantum network can't use locking, our universe has no common time so it can't use synchrony, and the quantum network has no memory storage so it can't use buffers. The quantum network can't wait for locks or clocks, and has no buffer memory, so how can it avoid transfer errors?

[7] Or CSMA/CD – Carrier Sense Multiple Access/ Collision Detect. In this decentralized protocol, *multiple* clients *access* the network *carrier* if they *sense* no activity but withdraw gracefully if they detect a collision.

2.4.4. The pass-it-on protocol

The transfer protocol now proposed is staggeringly simple. It is that quantum waves are passed on as soon as they are received, so they spread like ripples in a pool. A pebble that falls onto a pool pushes the water down until it rebounds, and that up-down displacement spreads as ripples on its surface. Likewise, a photon starting on a quantum network surface is also an up-down displacement passed on, giving the quantum ripples we call light.

If quantum waves are processing waves, each point involved has to do two things: run the process and pass it on. One might expect it to run the process first then pass it on but to avoid transfer losses, it is better to pass the processing on as soon as it is received. The pass-it-on protocol is then that any processing received is passed on immediately, to ensure that it isn't lost.

If a transfer sent to a point waited for it to finish what it was doing, the speed of light would vary for the same route, but it doesn't. This implies that each transfer is received as an interrupt, which in computing is a signal that has priority over anything else a processor is doing. For example, in Windows, pressing Ctrl-Alt-Del keys together interrupts the CPU to run the Task Manager.

The pass-it-on protocol essentially prioritizes transfers over anything else, so the speed of light is constant because light waves are always immediately passed on. Light spreading throughout the universe also helps synchronize the network, despite it being decentralized. The effect isn't perfect, but light interrupting points everywhere at a constant rate increases synchrony.

A weakness of this protocol is that transfers in a circle would give an endless interrupt loop that reduces processing, like the deadlock loop earlier. Fortunately, space expanding mitigates this, as new points of space have nothing to do for their first cycle. This reduces the loop build-up, but that a halo of light circles the galaxy center could explain dark matter (4.7.6).

In this protocol, nothing ever waits, so it is efficient, no transfers are lost, so it is reliable, and quantum waves are generated, so it is effective. It works well but if it did fail, even for a moment, not only our universe, but also its evolution, would be gone forever. The only recovery then would be to restart another universe from scratch.

2.4.5. Empty space is full

If only matter exists, the space between objects should be nothing at all. Nothing should do nothing, but we know that the vacuum transmits light, gravity, magnetism, and charge, and that isn't nothing. It is said that from nothing, nothing comes, but from our space comes the distance between objects, for if nothing separated objects in empty space they would be touching! A space that transmits waves and separates objects can't be nothing.

The Casimir effect illustrates this, as uncharged plates close together in a vacuum register a force pushing them together (Cole, 2001). Quantum theory predicts this pressure but a truly empty space shouldn't do this. Martin Reece, Astronomer Royal and Emeritus Professor of Cosmology and Astrophysics at Cambridge University, concludes that space isn't just the absence of matter:

> "*We know that the universe is very empty. The average density of space is about one atom in every ten cubic metres – far more rarefied than any vacuum we can achieve on Earth. But even if you take all the matter away, space has a kind of elasticity which allows gravitational waves – ripples in space itself – to propagate through it. Moreover, we've learned that there is an exotic kind of energy in empty space itself.*" (Martin Reece).

Space looks like nothing but is actually something, so how can that be? The current reply is field theory, that light travels by vibrating a field within space in a direction outside space, as Maxwell's equations describe. In effect, space hosts an invisible field that vibrates in an invisible direction to cause light. This is accepted because the equations work, but how can a physical field vibrate outside space? Field theory also lets virtual particles from this field push the Casimir plates apart, but what creates those particles? Field theory essentially allows empty space to have physical effects, as it does, but how can nothing host a field that generates particles?

The alternative now proposed is that the quantum network shows something or nothing as a screen shows an image or blankness. Empty space is then a screen null value, light is positive-negative values spreading, and matter is a constant positive or negative value. The following chapters give more detail, but basically this gives a single cause for space, light, and matter, namely the quantum network. It also lets space create distance, so the earth doesn't touch the moon because the null points of space separate them.

Why then does empty space have energy? If empty space is null processing, why isn't the result all zeros? The answer is that null processing isn't constantly null. A positive-negative null process is only zero when the cycle ends, so at any moment, some points in a region will be zero but others won't. Points will average zero over time but for an asynchronous network, as proposed here, they aren't all zero at once. Empty space isn't always empty, just as a blank TV screen can show static. Quantum theory doesn't allow space be constantly null, so:

"*… space, which has so much energy, is full rather than empty*." (Bohm, 1980), p242.

That space is something not nothing, and that it transmits light waves, implies a non-physical ether. Einstein also concluded long ago that some sort of ether had to exist for relativity to work:

"*…there is a weighty argument to be adduced in favor of the ether hypothesis*." (Einstein, 1920).

Strangely enough, modern field theory now supports the idea of a non-physical ether:

"*The ether, the mythical substance that nineteenth-century scientists believed filled the void, is a reality, according to quantum field theory*" (Watson, 2004), p370.

For Newton, space was a static tablecloth that presented objects like cutlery, but field theory sees it as an ocean that spits quantum foam and particles that jump like fish. But if empty space is full, what is it full of? Physical realism can't say, but quantum realism lets it be full of quantum processing.

When one looks out a window, one sees the view not the glass transmitting it. We know a glass is there if it is imperfect, if there is a frame around it, or if it can be touched. Now suppose that our window on reality has no imperfections so it can't be seen, is all around us so it has no frame, and accommodates matter so it can't be touched. It is like a perfect glass that reveals reality but doesn't show itself. It is perfectly clear, with no flaws or imperfections, so it can't be seen. It is boundless, without sides or edges, so it can't be seen around. And it accommodates matter, so it can't be touched. We walk, talk, and act within what we can't register, so we call it empty space, but actually what we call empty is full.

2.5. RE-ENGINEERING PHYSICS

Last century, the equations of physics were one-liners, like $E=mc^2$, but the equations of string theory today fill books. The low-hanging fruits of nature's tree of knowledge have been plucked it seems. The ladder of machine learning was expected to help, but thirty years of data crunching didn't alter the situation. Meanwhile, the theory front produced one wrong prediction after another, for as a physicist notes:

"*Ten thousand wrong predictions sounds dramatic but its actually an underestimate… all the extra dimensions … all the pretty symmetry groups, all the new particles … They were all wrong. Even if the LHC finds something new in the data that is yet to come, we already know that the theorist's guesses did not work out. Not. A. Single. One. How much more evidence do they need that their methods are not working*?" (Hossenfelder, 2018).

Fifty years without progress in physics is unprecedented, so it's time for a change. The change proposed now is to stop spinning what Hossenfelder calls theory-tales, and re-engineer physics from the data ground up.

2.5.1. The end of physics?

Modern physics has been stagnant for so long that some physicists predict *the end of physics*, as maybe:

"*… for the first time in the history of science, we could be facing questions that we cannot answer, not because we don't have the brains or technology, but because the laws of physics themselves forbid it.*" (Cliff, 2015).

Yet in the history of science, it wasn't the laws of nature that forbade questions but the laws of people, their dogmas. The main dogma of modern physics is materialism, the idea that everything is physical. No-one has ever proved it, so it's just an assumption, but it is said to be self-evident. Even so, the world of transistors, satellites, and cellphones we have today is based on equations about waves that aren't physical. According to materialism, quantum waves don't exist, but how then does light travel? And if empty space can have a physical effect, why not quantum waves? Relativity and quantum theory began with causes that aren't physical, like curved space and quantum waves, so why don't we study them further? It isn't nature that is stopping us, but our own dogmas.

Last century, physics left the safe haven of classical mechanics, hoping to discover how light moves in a vacuum, and how gravity acts from afar. Wandering in the desert of materialism, instead of finding a promised land, they found the quantum jungle, a weird place that seemed to ignore the laws of matter. Those who entered it returned with strange stories, like that it guided matter (Bohm, 1980), so the expedition leaders fenced it off with equations, calling it mythical, and banned all discussion of it. With nothing else to do, their followers built a great castle in the desert called the standard model. Today, it dominates a barren landscape because nothing grows around it.

Sitting in their castle, physicists invented theories like supersymmetry that predicted new particles, so they built a great machine to produce them, called the large hadron collider, but it didn't find any of them. Theories weren't working so they were altered to fit the data, but they still didn't produce anything. As one physicist concluded, the trouble with fundamental physics is that it isn't producing any new knowledge (Smolin, 2006). For example, string theory makes no predictions at all, and the multiverse is an untestable speculation that isn't even wrong (Woit, 2007). It seems that even the weeds of error don't grow in the desert of materialism. Today, the fizz has gone out of physics because what baffled Einstein and Feynman seventy years ago still baffles physicists today.

Speculating based on bad theories is bad but it still tells us what doesn't work. In contrast, speculating with no theory at all is worse because nothing is learned. Just as people stuck in a desert start to see mirages after a while, physicists are now just imagining things, as these paper titles illustrate:

1. *We may have spotted a parallel universe going backwards in time*. (Cartwright, 2020).
2. *Neutrinos may explain why we don't live in an antimatter universe*. (Crane, 2020).

The key word in the above titles is "may". Fifty years of physics can be described as maybe WIMPS, maybe strings, maybe time travel, maybe supersymmetry, maybe a multiverse, and so on, one mirage after another. There are papers on white holes, large extra dimensions, time travel, closed time loops, wormholes, heavy sterile neutrinos, and super-particles, all hoping to be the next revolution in physics, but they weren't. In 2018, a New Scientist cover story speculated about axiflavons from a hypothetical flavon field and concluded:

"*It's thrilling stuff, if for the moment it is only conjecture*", New Scientist, August, 2018, p31.

It was a thrilling conjecture but years later, nothing has changed! Physicists sitting in a semantic desert are dreaming theories and if they stay there, the next fifty years will be as barren as the last. Trying to explain quantum theory based on materialism is like looking for the keys you lost in a jungle in the desert around it because it is easier to look there. When physics quarantined the quantum jungle, it turned its back on the greatest discovery of humanity, that quantum events really do cause physical events.

The way out of this stagnation is to change the methods of physics, as Hossenfelder says:

"*The major cause of this stagnation is that physics has changed, but physicists have not changed their methods… Instead of examining the way that they propose hypotheses and revising their methods, theoretical physicists have developed a habit of putting forward entirely baseless speculations.*"

Speculating without theory is like throwing mud at a wall and hoping for a portrait, and speculating without theory is like drawing castles the air that have no foundations. For example, string theory has 10^{500} rooms based on no data, despite thousands of papers. So, is physics helpless before what makes no physical sense? How then can physics study the quantum mystery if materialism can't?

Luckily, science has a precedent. When other disciplines face what their conventions can't explain, they use grounded theory. It works when other methods fail because it isn't based on any assumptions at all, just the data. To use it, physics would have to abandon its assumptions about matter, but they are going nowhere, so what is the loss? That matter can't explain everything isn't the end of physics, but a new beginning.

2.5.2. Grounded physics

When Europeans first visited China, its society made no sense to the colonial mindset, as the constant bowing seemed unnecessary and they didn't understood the importance of face. Only later was it realized that in China, groups create individuals not the other way round, so being excluded from one's family, clan, or society was worse than a death sentence, while bowing and keeping face avoided this. Social scientists called the method that led to this discovery grounded theory, which as the name implies, is to first gather data, then theorize about it. Scientists studying new cultures learned to first watch, listen, and record, then form theories to test the next day. Repeating this method daily then produced a grounded theory, based on the data not bias.

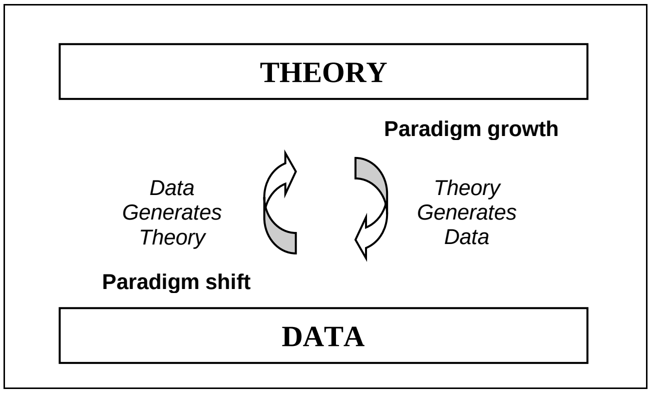

Figure 2.14 The relation of theory and data in science

Grounded theory avoids colonial bias but seemed at first to reverse normal science, until Kuhn noted that science has always advanced by paradigm shifts (Kuhn, 1970). Testing theory prediction against data is then normal science, that grows a paradigm, and using the data to generate a new theory by a paradigm shift is also science. Science then includes:

1. *Paradigm growth:* Theory generates data predictions (normal).
2. *Paradigm shift:* Data generates a new theory (revolutionary).

In paradigm growth, theory generates new data, while in a paradigm shift, data generates new theories (Figure 2.14). Normal science progresses gradually, as sediment builds up a rock, but paradigm shifts change the theory landscape suddenly, as an earthquake does. For example, the paradigm shift from Galen's theory of miasma to a germ theory of disease was an intellectual earthquake that sunk one theory and raised another. Grounded theory is the scientific method that supports paradigm shifts.

Kuhn further suggested that in the history of science, paradigm shifts are needed when traditional theories stagnate, to raise a new theory from the data ground up. In Figure 2.14, science connects data and theory either way, to generate data from theory, or to generate theory from data. Both ways are science because both connect data and theory to increase understanding.

It follows that physics could be approaching quantum reality as the colonials did China, with a bias. The bias is materialism not colonialism but the problem is the same. Physics sees only particles not waves, but quantum theory is based on waves not particles, so it made quantum waves imaginary, but what if they aren't? If a paradigm fails to predict year after year, as particle theory has, is the answer more of the same? Throwing ideas at a wall to see what sticks doesn't work, so it's time to revisit the data ground, based on grounded physics.

Grounded physics applies grounded theory to physics by looking at the data from a quantum wave perspective, not a matter particle perspective. It aims to explain quantum reality on its own terms not ours. As will be seen, taking off the blinkers of materialism suggests a universe based on waves not particles, that pulsates with energy not emptiness. A grounded theory of physics would then be based on data not bias.

2.5.3. Reality is quantum

Reverse engineering is grounded theory for computing, as it deduces what causes screen events. When we observe a screen, what changes it is unseen but we can deduce the cause, then refine that deduction by further observations until it reliably predicts what happens next.

Reverse engineering, a part of design science, can apply to physical events produced by quantum processing waves. These waves can't be observed physically, but if unseen wi-fi waves can fill our screens with images, unseen quantum waves could do a similar thing for the screen of space. Reverse engineering then explains physical events based on quantum events, given that quantum reality is:

1. *A network.* So physical events are discrete not continuous.
2. *That transmits waves.* So entities move as waves not particles.
3. *That vibrate at right angles to space.* So space isn't complete in itself but contained.
4. *Until they interact in physical events.* So physical events aren't fundamental but derived.

These features of quantum reality suggest that our world isn't as physics expected. Materialism assumes particle entities that move on single paths through empty space, but wave entities on a network spread on many paths. Which view is right then, particles or waves? For most empiricists, the answer is obviously particles, because the laws of physics work, but those who made those laws also imagined methods that assumed the opposite. These methods were accepted because they worked, and because mathematics doesn't make claims about reality, but the result is that physics uses methods based on quantum features that contradict materialism. For example:

1. *Calculus.* The calculus used throughout physics began as a thought experiment, that infinitesimals predict physical events in the limit. It worked brilliantly, but that space and time change in tiny steps contradicted the assumption of continuity, so it became just a mathematical tool that is used but not believed in. Calculus was rejected as a reality description because it denied a canon of materialism, but if space and time really do change in quantum pixels and cycles [8], then physical events are discrete not continuous.
2. *Sum over paths.* Feynman's sum over paths theory also began as a thought experiment, that quantum particles take every path to a destination then pick the best one. Again, it worked brilliantly, but that entities move as waves contradicted the assumption that they are particles, so it also became a mathematical tool that is used but not believed in. Feynman's theory was rejected as a reality description because it denied a canon of materialism, but if quantum entities really do move as waves, then physical entities must also move as waves not particles.
3. *Complex numbers.* Complex number theory was another thought experiment, that electromagnetic waves like light rotate in a plane outside our space. Again, it worked brilliantly, but having a plane outside space contradicted the assumption that space is complete, so it also became a mathematical tool that is used but not believed in. Complex number theory was rejected as a reality description because it denied a canon of materialism, but if there really is a dimension outside our space, then space isn't complete but contained.
4. *Quantum mechanics.* Quantum mechanics was yet another thought experiment, that unseeable quantum waves interact to cause physical events. Again, it worked brilliantly, but that quantum waves cause physical events contradicted the assumption that those events are fundamental, so it also became a mathematical tool that is used but not believed in. Quantum mechanics was rejected as a reality description because it denied a canon of materialism, but if quantum events really do cause physical events, then physical events aren't fundamental but derived.

All the above methods, of calculus, sum over paths, complex numbers, and quantum mechanics, are used in physics because they work, but what they imply is ignored because they are called imaginary. But if these methods are good enough to use, why aren't they good enough to believe? The answer it seems is that they deny materialism, an ancient belief of Aristotle. For if the method of calculus is true, then our world isn't continuous. If the sum over paths method is true, then entities don't move as particles. If complex numbers are true, then our space isn't complete. And if quantum theory is true, then physical events aren't fundamental. This leaves physics caught between what it believes and what works, like a sailor who says the earth is flat but uses global coordinates to navigate.

[8] For any calculus involving time, replace *dt by dp*, a small number of processing cycles. Now *dp* can indeed tend to zero because there cannot be less than one processing cycle.

Yet when evidence contradicts belief in science, isn't the latter supposed to win? If global coordinates work, doesn't that mean that the earth isn't flat? Based on the evidence, it isn't quantum theory that is imaginary but materialism, and the other methods suggest the same. Why then don't physicists want their equations to be true, as they would be if quantum waves exist? Wouldn't that make physics simpler?

The answer seems to be a dread that accepting quantum reality will open the door to magical thinking, where quantum powers allow psychic healing, telepathy, psychokinesis, and other miracles (Chopra, 1989). Physics doesn't want to go back to a dark age of God theories, that explain everything but predict nothing.

Yet this fear is unjustified because reverse engineering doesn't work that way. For example, quantum computers are powerful but not magical because quantum waves spread, collapse, restart, and entangle based on quantum laws not an all-powerful being. They act in physically impossible ways but they are lawful, so they aren't miracles. That reality is quantum then doesn't allow miracles, any more than that it is physical does. Quantum realism is no more a God theory than a quantum computer is a God computer.

Using reverse engineering to develop a model of how quantum processing works doesn't open a door to quantum mysticism, but it may explain what materialism can't, which why quantum theory works in the first place.

2.5.4. A quantum model

Last century, physics invented a tale of quantum waves that spread at light speed then collapse instantly into physical events that begin the waves again. It made no sense, because physical waves can't restart like that, but these strange waves predicted atomic events amazingly. The result was modern technologies like (Jenner, 2014):

1. *Transistors* that run devices like smartphones work thanks to quantum laws.
2. *Medical devices* like MRI (Magnetic Resonance Imaging) look within the body without surgery thanks to quantum laws.
3. *Global Positioning Systems* (GPS) let us navigate the world thanks to quantum laws.
4. *Lasers* scan barcodes at supermarkets thanks to quantum laws.
5. *Solar panels* convert sunlight into electricity thanks to quantum laws.
6. *LEDs* (light-emitting diodes) run the sensor lights on TVs thanks to quantum laws.

Without quantum laws, these technologies wouldn't exist, but last century physics made the theory behind them imaginary because it was physically impossible. But if the technologies are real, how can their theory be imaginary? One possibility, not recognized initially, is that quantum theory describes processing waves spreading on a network, because such waves can:

1. *Evolve stepwise.* Quantum waves evolve one step at a time. Physical waves don't do this, but waves on a network pass from one point to the next in a stepwise fashion. Quantum waves could then evolve step-by-step because each step is a network cycle.
2. *Superpose to a limit.* Quantum waves superpose probabilities up to a limit of one. Physical waves don't do this, as they can be any height, but waves on a network can't exceed the capacity of a network point. Quantum waves could then have a size limit because each network point has a bandwidth, beyond which it overloads and reboots.
3. *Collapse instantly.* Quantum waves collapse instantly to restart at a point. Physical waves can't do this, but a wave run by a server can restart at a point. A quantum wave could then collapse instantly because a network point reboots to restart its server.

4. *Entangle at a restart point.* When quantum waves restart at the same point in a physical event, they entangle to become one. Physical waves don't do this, as they just pass through each other, but two processes restarting at the same point could merge into one. Quantum waves could then entangle at a point because their servers merge their processing.

Later chapters give more details, but essentially quantum weirdness isn't weird in computer terms. Processing waves on a network can evolve stepwise, superpose to a limit, collapse instantly, and entangle by the nature of processing. The resulting model of how quantum events cause physical events has these aspects (Figure 2.15):

1. *Servers*. Servers generate and restart quantum waves.
2. *Network*. Quantum waves spread and superpose on the network.
3. *Reboot*. Until a point overloads and reboots, to request server restarts.
4. *Physical Event*. A physical event restarts the waves at the same point, which entangles them.

A photon is a processing wave that spreads on a network until it overloads a point, in a physical event that restarts it again, so quantum waves are never lost. If quantum waves evolve stepwise when passed on, superpose when they overlap, collide when they overload a point, collapse when they restart, and entangle when their servers merge, then quantum theory is literally true.

The only strange thing about this model now is that the last step is an observed physical event. According to quantum theory, we observe a photon by interacting with its quantum wave in a physical event. This is an action, so we create our observation of the photon. The quantum waves around us only become physical events when "touched", like a painting that appears only when painted, one brushstroke at a time, and we aren't the only painters, as atoms also paint events. The surface painted on, which we call space, can curve, and the clock counting the strokes, which we call time, can slow down, as Einstein deduced. Relativity gives each painter their own canvas and clock, so space and time are generated locally, along with each physical event.

If time and space began when our universe did, before that they didn't exist. Hawking concluded the same, arguing that nothing existed before our universe (Hertog, 2024), but how can nothing create a universe? The alternative is that what began our universe also began its space and time. Physical realism doesn't say how time and space began, let alone matter, but quantum realism lets space and time begin with the first physical event.

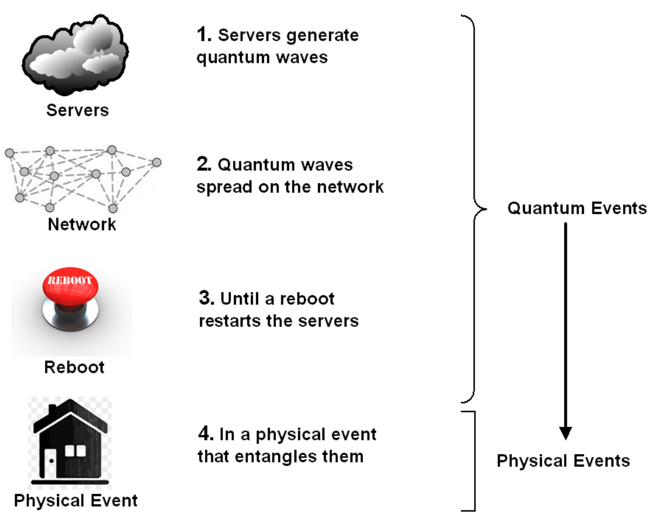

Figure 2.15. Quantum events create physical events

To think the first event was just about light or matter is to underestimate it, as it needed space and time as well. We can picture making objects but making time and space is hard to imagine Scientists expected the first event to be about matter, and theologists expected their divinity to create a perfect world, but the evidence is that our universe didn't begin with humans, animals, sky, or earth as they are now, but with what led to them. Our universe then began as a primal seed that after fifteen billion years has grown into galaxies, stars, planets, life, and us. The first event made not only things but also space and time, and not only then but also now, so the rabbit-hole of quantum reality runs deeper than even its advocates suppose.

Table 2.1 compares quantum realism with physical realism for space and time, so the reader can decide which explains the evidence better. The following chapters use the above model to explain the behavior of light (Chapter 3), matter (Chapter 4), and relativity (Chapter 5). They also make a testable prediction that current theory denies -

that pure light can collide (4.5.9). Chapter 5 ends Part I, on the observed world, and Part II applies the same model to the observer.

Table 2.1. Chapter 2 summary: Physical realism vs. quantum realism for space and time

Physical Realism	Quantum Realism
Physical realism. Only the physical world exists so: a) Physical objects cause all physical events b) Randomness is not possible c) Replaying physical events is reloading reality d) One day we will upload and reload ourselves	**Quantum realism**. Only the quantum world exists so: a) Quantum processing causes all physical events b) Randomness is possible c) Replaying physical events is not reloading reality d) Quantum reality can never be saved or reloaded
Space. Is the "no-thing" between matter, so it is: a) *Empty.* Yet it hosts virtual particles b) *Continuous.* Yet there is a Planck length c) *Containing.* Space contains all things in itself d) *Expanding.* But how can nothing expand? e) *Absolute.* A cartesian space has an absolute center f) *Doesn't mediate light.* So light is a wave of nothing g) *Unlimited.* So the universe can exist at a singularity h) *Always zero.* Which quantum theory denies	***Space***. Is quantum null processing, so it is: a) *Full.* Null processing just looks empty b) *Discrete.* Hence there is a Planck length c) *Contained.* Space is merely a 3D surface d) *Expanding.* Into a larger quantum bulk e) *Relative.* Each quantum node paints its own links f) *Mediates light.* So light is a wave "on" space g) *Limited.* The bandwidth of space is a black hole h) *Averages zero.* As quantum nodes are asynchronous
Time. Objects exist inevitably in time, so it is: a. *Continuous.* Yet there is the Planck time limit b. *Real.* Yet it slows down with object speed c. *A dimension.* That objects can time-travel in? d. *Reversible.* According to every law of physics	***Time***. Time is based on quantum cycles, so it is: a. *Discrete.* Planck time is one quantum cycle b. *Virtual.* It slows down with processing load c. *Not a dimension.* Time travel is impossible d. *Irreversible.* As a physical event is a reboot
Directions. Moving objects are self-directed so: a. *A straight line* is a moving object property b. *Gravity* bends space to alter straight line paths c. *Angles.* Every angular direction is possible	***Directions***. Moving objects are network transfers so: a. *A straight line* is the fastest network transfer path b. *Gravity* alters the fastest network transfer path c. *Angles.* Are quantized for a quantum event
The big bang. The universe began entire all at once: a. *Cause.* Nothing at all, as the universe is all there is b. *Start.* The physical universe started as an infinitely dense singularity at a dimensionless point c. *Inflation.* A huge anti-gravity field from nowhere then expanded the singularity faster than light d. *Inflation stopped.* After 10^{-32} of a second that field conveniently disappeared forever e. *Cosmic back-ground radiation* expanded "out" so it should be far away at the cosmic edge by now	***The little rip***. The universe began as a tiny "seed": a. *Cause.* The previously existing quantum network b. *Start.* The physical universe began when one photon was created in one unit of space c. *Inflation.* The extreme energy of the first photon caused others to follow suit in a chain reaction d. *Inflation stopped.* Inflation also generated space that diluted the first light to stop the chain reaction e. *Cosmic back-ground radiation* expanded inside a spherical surface so it is still all around us today

DISCUSSION QUESTIONS

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

1. Can information be defined in purely physical terms? Do so or explain why it isn't possible. (2.1.2)
2. Does a hologram of past physical events replay reality? What is missing? (2.1.3)

3. Can one copy a physical state? What about a physical event? What about a quantum state? (2.1.4)
4. How does quantum processing differ from physical processing? Why is it so powerful? (2.1.5)
5. If the physical world is digital, what is its resolution and refresh rate? (2.2.1)
6. State Zeno's paradoxes. How does physics resolve them? What does resolve them? (2.2.1)
7. Is space something or nothing? If nothing, what transmits light? If something, what is it? (2.2.2)
8. Would a network generating our universe be centralized or distributed? Explain why. (2.2.4)
9. Why do circular dimensions explain our space better than linear dimensions? (2.2.5)
10. How can space expand everywhere at once, as physics says? (2.2.6)
11. State one disadvantage of a polar space. Why doesn't it matter for our space? (2.2.7)
12. What does a dimension outside our space imply that one curled up within it doesn't? (2.2.8)
13. If reality has a fourth dimension, why can't we enter it? (2.2.8)
14. If light is a transverse wave, like a wave on a lake, on what surface is it vibrating? (2.2.9)
15. Traveling at near light speed slows down time, so would you live longer? (2.3.1)
16. Is there any evidence for time travel in physics? Why is it unlikely? (2.3.2)
17. Why can't quantum entities go back and forth in time? (2.3.3)
18. Is there an alternative to the block theory of time? What is it? (2.3.4)
19. Why is cosmic background radiation from the early universe still all around us? (2.4.1)
20. What caused the initial inflation of the universe and what stopped it? (2.4.2)
21. What happens if a network data transfer fails? How do our systems avoid this? (2.4.3)
22. How could a quantum network avoid transfer losses? (2.4.4)
23. Is the vacuum of space empty or full? If full, what is it full of? (2.4.5)
24. Why is theoretical physics no longer advancing? (2.5.1)
25. What can science do when a theory no longer generates new knowledge? (2.5.2)
26. Do the equations of quantum theory describe what is imaginary or real? Justify. (2.5.3)
27. Why do physicists call what quantum theory describes imaginary when it predicts physical events? (2.5.3)
28. Is quantum realism a God theory? Why or why not? (2.5.3)
29. If quantum waves are processing waves, what is a physical event? (2.5.4)

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