# Chapter 2. Simulating Space and Time

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

Walt Whitman

Every virtual world embodies a space and time to those living within it. This chapter analyses the processing a virtual world would need to generate a space and time that appears to its inhabitants as ours does to us.

## 2.1. THE PRIMAL REALITY

Quantum theory defines the quantum processing that quantum realism proposes generates the physical world as a virtual reality. This section contrasts that processing, which is based on qubits, with the classical bit-based processing we are used to. The *primal reality* that generates quantum processing is proposed to originate from a *quantum network*.

### 2.1.1. The quantum network

The proposal that the physical world is the *output* of something else is radical but it isn't new:

1. *Fredkin.* Proposes that the physical world as an output "*…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 beyond the physical is "… *the Grid, that ur-stuff that underlies physical reality*" (Wilczek, 2008 p111).
3. *Wheeler*. His phrase "*It from Bit*" implies that matter is in some way a processing output.
4. *D'Espagnat*. Proposes a "*veiled reality*" that creates time, space, matter and energy (D'Espagnat, 1995).
5. *Campbell.* Proposes that a "*Big Computer*" outputs our reality (Campbell, 2003).
6. *Barbour.* Imagines a quantum reality where "*The mists come and go, changing constantly over a landscape that itself never changes*" (Barbour, 1999) p230.

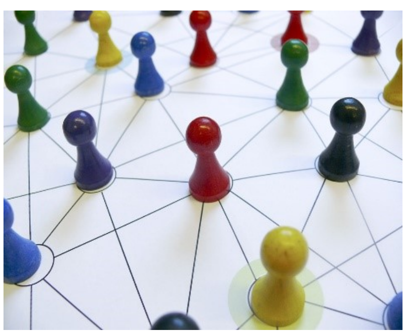

*Figure 2.1. A* network *of nodes*

Quantum realism takes these ideas a step further, arguing that Fredkin's *Other* is the quantum reality all around us now, that Wilczek's *Grid of "ur-stuff"* is the quantum network*,* that Wheeler's *It from Bit* is actually *It from Qubit,* that D'Espagnat's *veiled reality* is the unseeable quantum world*,* that Campbell's *Big Computer* is quantum processing, and that Barbour's *landscape that never changes* is the primal reality that existed before our time and space began. Hiley recalls that Feynman thought of space as a *processing network* of nodes (Figure 2.1):

> "*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*" (P. Davies & Brown, 1999) p138

The network proposed here isn't physical because what creates a virtual reality doesn't depend on what it creates. If that "hardware" is quantum reality, then it follows the rules of quantum theory not of its physical output. It is also expected to have the general properties of a processing network, such as:

a. *Nodes.* That run quantum processing.
b. *Processing.* That is based on qubits.
c. *Channels.* That allow transfers between nodes.
d. *Density*. That reflects the number of channels per node.
e. *Bandwidth*. That is the capacity of node channels.
f. *Protocols.* That decide what happens if an exception occurs.

Before exploring how a quantum processing network could create a space and time like ours, it is necessary to clarify that information isn't a physical thing.

### 2.1.2. Information isn't physical

Quantum realism proposes that the quantum network can be understood in terms of information theory but not in terms of how we implement information theory physically.

Modern information theory began with Shannon and Weaver, who defined *information* as the power to the base two[1] of the number of *choice options* (Shannon & Weaver, 1949). By this definition, a choice between two physical options is one bit of information because two is two to the power of one, and a choice between four options is two bits because four is two to the power of two. By this logic, two to the power of eight, or 256 is 8 bits or one byte. Equally a choice of one option, which is no choice at all, is zero bits. *Processing* was then defined as changing information, i.e. the *event* of making a new choice.

Hence while the *choice* between two states is one bit, according to information theory a physical state in itself has no information at all because it is just one way. A book "contains" information but has *zero information in itself* because, being physical, it is fixed in one way. This may seem wrong but it isn't, as hieroglyphics no-one can decipher do indeed contain no information. A book only gives information when a *reader* decodes it, and that depends entirely on the *decoding context,* so reading every 10th letter of a book, as in a secret code, gives a different message with different information.

The amount of information "in" a physical state depends on the *assumed* number of physical states it was chosen from. 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, say Aardvark, can represent many bytes. It is because the information in a physical message depends on the *decoding context* that data compression can store the same data in a smaller signal, using more efficient encoding. If information was a physical thing, data compression couldn't pack the same data into a physically smaller signal! In general, the information in a physical signal is undefined until a reader decodes it. Only when sender and receiver agree on the encoding-decoding context can they exchange information.

It follows that *information only emerges from a physical state when an observer is added*. The same applies to information in a book or database - the states <u>in themselves</u> contain no information at all until read. If one writes a book in English say, that language is the encoding context that allows communication. The receiver can only extract the information the sender put in if they know the encoding context.

If processing is defined as creating information, *writing a book is processing*, as one can write it in many ways, and *reading a book is also processing*, as one can read in many ways, but the physical book itself, being just one way and no other, is empty of information. Information stored as physical states doesn't exist without a reader to decode it by a series of dynamic events. By Shannon and Weaver's definition, *processing is the dynamic means by which static information is encoded and decoded so the information in a physical book literally doesn't exist until an observer decodes it.*

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

#### 2.1.3. Reloading reality

Information theory clarifies why a physical world can't output itself, because that would require a context specified in advance based on physical states that are not yet defined. As McCabe concludes:

*"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).

The same physical world can't be both processor and output but can one part save and reload another? Could we save and reload physical reality as we do information? To save a matter scene as we do a game scene requires a data structure that existed before the scene did, so it can't be based on matter. To save a game requires a pre-defined data structure, so if a new game version changes that, old saves don't work! To reload a universe would likewise require a known data structure else the result would be nonsense, just as reloading a WordPerfect file into Word gives gibberish because Word doesn't know WordPerfect's "*interpretive context*", as McCabe argues.

Imagine our universe frozen in a static state at a moment in time, as innumerable physical states that have no information at all in themselves. Information requires an observer to decode it but who could "read" it? Not us, as we would be frozen too! A frozen world without an observer would be as empty of information as this page is without a reader. To save and reload a physical universe one must define its data structure and exist outside it!

When we store movies in file to replay later, we need an agreed format like mp3. To play the file, we also need something to dynamically play it, like a laptop or projector, so without a projector to play it, there is no movie. Likewise, a computer plugged into a power source is needed to run a program file. So even if one could save the universe as static data, what "projector" using what power source could reload and run it? Information stored as a static file always needs a dynamic system to reload into.

Trans-humanists take the mind to exist entirely as information encoded in the physical brain, so expect that we will soon be able to upload the mind and download it to a new, younger, body and so live forever. However even if we could make a perfect physical copy of a brain at a moment, that is no better than taking a photo in a movie theater and taking a photo of a movie doesn't "store" it, as one frame is not a movie. Even many photos taken and replayed in sequence doesn't "resurrect" the person, any more than playing a movie of a dead person resurrects them. Recording a physical scene and replaying it as a *hologram* may *emulate* a dead relative but it doesn't *recreate them*. The viewing experience would be real but the "person" viewed wouldn't experience life as an observer. Information based on physical states still needs an observer, so one has to copy the observer as well. In the same way, saving a multi-player online game doesn't save the other people playing it because they aren't "in" the game. Chapter 6 returns to the issue of the need for an observer in more detail.

Since genes *are* information, why not copy genes to create a biological copy of ourselves? This can be done but nature already does it, as identical twins are from copies of the same original cell. Yet the result is twins that are two different people not the same person. A clone of me doesn't make another me but another person. Even if that copy of "me" has experiences, it still isn't me if I don't experience what the clone does.

Something is missing in the reloading reality idea and it is the quantum reality behind physical events. If that is what "runs" physical reality, the question reduces to whether quantum processing can be saved and reloaded.

#### 2.1.4. Quantum processing can't be saved

To truly copy physical reality, one must know what it actually is in the first place. It is clear that a photo of me isn't me, nor is a movie of me, nor is a biological clone of me. But if physical events are created by quantum processing, as quantum theory implies, can we copy the quantum processing? If quantum processing creates physical reality, to *really* duplicate a physical event one must copy the quantum processing behind it.

Unfortunately, the *quantum no-cloning theorem* explicitly excludes this, stating that it is impossible to create an identical copy of a quantum state because to "know" a quantum state is to collapse and so destroy it. Hence talk of uploading and downloading universes, minds or ourselves has no basis in quantum theory or information theory. It is all just wishful thinking.

A key corollary is that the quantum network proposed can't use static storage because it is impossible to store quantum activity in any way by the *quantum no-cloning theorem*. The quantum network acts in a way that doesn't have the luxury of static storage. Like a star that constantly shines, quantum processing is constant activity without pause. Cell-phone and Internet networks use buffers to handle overloads but a quantum network can't use memory of any sort to store what it does. Computers and cell-phones save and reload physical states but quantum computers can't store or reload quantum states. Quantum theory doesn't allow RAM, ROM or buffers of any sort.

By this logic, McCabe's argument that physical reality can't come from information based on physical reality doesn't apply to quantum reality. Classical processing needs a physical context to exist but quantum processing doesn't depend in any way on physical reality. The original quantum reality just is what it is.

#### 2.1.5. The processing of processing

Quantum theory describes *quantum waves* that expand at the speed of light until they are observed and collapse to a physical event. Quantum realism interprets these waves as *processing waves*, as follows.

Processing is *the creation information* by choosing one physical state over others, so our information is *static*, based on a fixed state while processing is *dynamic,* based on a choice event. Information derives from a known physical state while processing involves an unknown event by the definition of choice. And processing on our networks doesn't spread, so it is in this sense static, as if your computer runs a program, it doesn't spread to the Internet by itself. Now imagine a *dynamic process* that once it starts on any network node immediately spreads to its neighbors, and this repeats in the next cycle. It follows that quantum processing is *the creation of processing*, just as processing is the creation of information. Quantum processing is then *processing creating processing*.

Quantum processing on a network then creates a processing wave that behaves like a quantum wave. Starting in one node, it not only runs a process in that node but also immediately passes it to all its neighbors. The next network cycle, those nodes also begin the process and again pass it on to their neighbors, and so on. Just as a water wave spreads the activity of water, a quantum processing wave spreads a quantum process.

Processing waves are *events* not *things* and the only way to "save" an event is to run it again. As in process philosophy, the premise is that existence is dynamic and that dynamic nature is fundamental to reality. One can save and reload static states but not events, as the act of storing an event is another event. The next chapter explains in detail how quantum waves match the properties of light waves, but for now note that it accounts for two key properties of light. First, that light waves always *spread*, and second that light as a quantum wave can *collapse*. Unlike physical waves, a *processing wave* can restart from any one of its many locations if a node point *reboots*. That light is a *quantum processing wave* offers a possible explanation for quantum collapse.

Quantum processing as the creation of processing is what makes quantum computing, based on qubits, more powerful than physical computing. A bit is a choice between two states but a qubit also allows their *superposition,* as a one-bit computer only has the values 0 or 1 but a one-qubit computer can also be 0/1 and 1/0, so it can be zero and one *at the same time*, as in Schrödinger's alive/dead cat. A bit is one process making one choice in one place but a qubit is two choice processes and that allows superposed options. Superposition lets quantum processing choose all possible options at once rather than just try one at a time.

The result is that quantum processing isn't just better than physical processing, it is *exponentially* better, so doubling my computer's processing needs double the bits but adding just one qubit to a quantum computer doubles its power[2]. If physical processing is like going to the moon, quantum processing is like going to the nearest star in the same time. As expected, what generates physical reality is far beyond anything we can physically achieve.

Quantum waves are all around us all the time and they never stop. We don't "make" quantum computers as we do physical ones but just use what naturally occurs. We tap into quantum processing rather than make it work, just as we tap into the sun's warmth but make a fire to warm us. *We don't create quantum processing, it creates us.*

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

The revelation of quantum theory, that quantum waves cause physical events, was the greatest discovery of last century, on a par with evolution the century before and finding that the earth goes round the sun centuries earlier. But while orthodox religion denied the earlier advances, orthodox science denied Heisenberg's conclusion that:

"*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

Bohr denied the world of possibilities that quantum theory describes by calling it unreal. That orthodoxy denies innovation is no surprise but who expected scientific orthodoxy to be the denier? Imagine if astronomers believed the sun went around the earth but still used heliocentric equations. That would be preposterous but physics today uses equations based on quantum waves that they deny exist! It's time to explore the dangerous idea of quantum reality.

## 2.2. SPACE AS A QUANTUM NETWORK

This section considers how a quantum network spreading quantum processing could simulate our space.

### 2.2.1. Continuum problems

Continuum problems have plagued physics since Zeno's paradoxes two thousand years ago (Mazur, 2008):

1. If a tortoise running from a hare sequentially occupies *infinite* points of space, how can the hare catch it? Every time it gets to where the tortoise was, the tortoise has moved a little further on; OR
2. If space-time is *not* infinitely divisible, there must be an *instant* when the arrow from a bow is in 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, e.g. an electron as a dimensionless point has infinite mass and charge density unless one assumes other dimensions as string theory does. Physics handles the infinities of quantum field theory by the mathematical trick of *renormalization,* that makes the infinities of field theory go away by requiring particles to interact via other particles in Yang-Mills interactions. 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!*"

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."*

Renormalization pulls physical reality from the quantum hat although continuity is a mathematical convenience not a proven empirical reality:

"*... 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

Quantum realism concludes that space isn't continuous because a digital reality has no half pixels and time isn't continuous because it has no half cycles. Processing by definition chooses from a *finite* set that doesn't allow *infinite* values. It then answers Zeno's questions as follows:

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

Denying the infinitely small avoids the infinitely large. A digital world of irreducible pixels and indivisible ticks makes the infinities of continuity disappear, like ghosts in the day. Reality as a series of frames strung together, as in a movie, resolves the paradoxes that continuity cannot.

Our space breaks down at the order of Planck length because it is *discontinuous*. To study the very small needs short wavelength light that is high energy light, but putting too much energy into a space gives a black hole that hides information from us. If you probe the black hole with more energy, it expands its horizon to reveal no more, so nothing below the Planck length can be known. Planck length and time are the irreducible limits of our reality.

This predicts what current physics doesn't, that repeatedly dividing our space gives a pixel that can't be split and repeatedly dividing our time gives a cycle that can't be paused. Just as closely inspecting a TV screen reveals only irreducible dots, closely inspecting our space reveals irreducible Planck lengths. If physical reality is a screen image, the Planck limits are its resolution and refresh rate, so the pixel size of physical reality is $10^{-33}$ meters and its refresh rate is $10^{43}$ times per second.

### 2.2.2. Is space nothing?

*Does space itself exist?* This question has concerned the greatest minds of physics. Simply put:

*If every matter object in the universe disappeared, would space still be there*?

Newton saw space as the canvas upon which God painted, so it would still exist even without objects. In contrast Leibniz considered a substance without properties unthinkable so to him space was based on object relations, just as a meter was defined as the distance between two marks on a platinum-iridium bar in Paris. If objects only move with respect to each other, he concluded that without matter there would be no space.

Newton's reply to Leibniz was a hanging bucket of water that spun around (Figure 2.2). 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 when it initially spins relative to the water the surface is flat, and when later it is concave, the bucket and the water spin at the same speed. In a universe where all movement is relative, a spinning bucket should be indistinguishable from one that is still. If an ice skater spins in a stadium his arms splay out by the spin. One *could* see this as relative movement, as the stadium spinning round the skater, but why then do the skater's arms splay? He concluded that the skater *really is spinning* in space (Greene, 2004) p32.

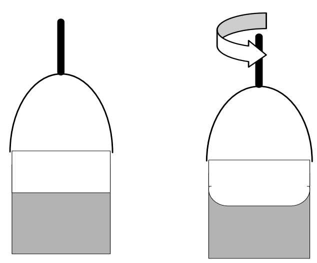

*Figure 2.2 Newton's' bucket.*

This seemed to settle the matter until Einstein showed that objects actually do move *relative* to each other. Mach then resurrected Leibniz's idea, arguing that the water in Newton's bucket rotated with respect to all the matter of the universe. In a truly empty universe, Newton's bucket would stay flat and a spinning skater's arms would not splay, but this isn't testable as one can't empty the universe. This resort to speculation reflects how disturbing some physicists find the idea of a space that is:

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

How then could a virtual space handle object interactions? There are two options:

1. *Centralized.* Give each particle an *absolute* position then compare all positions every cycle and if any are equal, then a collision has occurred. To the inhabitants of this virtual reality, space would indeed be truly nothing and potentially continuous. Yet as the particles increase the interactions grow geometrically, as each point must be compared to every other point every cycle. For a simulation the size of our universe, the processing required is unimaginable.
2. *Distributed.* Let each point of space be a node with a pre-allocated processing capacity. Now a collision is when a node gets more processing than it can handle. To the inhabitants of this virtual reality, space isn't continuous and does exist apart from the objects in it. This tactic seems wasteful as empty space is allocated null processing but has the advantage that expanding the system also adds more processing.

Reverse engineering prefers the distributed option because the processing is finite. It implies that a point of empty space can show a dot or "nothing", just like a screen point, where showing nothing is null processing. This means that if every object in our space disappeared, it would still exist, just as a screen still exists even if no image is shown, supporting the current verdict of physics that:

"*space-time is a something*" (Greene, 2004) p75

Empty space as *null processing* is neither the passive canvas of Newton nor the nothing of Leibniz because null processing is something not nothing and it is active not passive.

#### 2.2.3. A Cartesian space

That space is a "something" raises the question *What does it do?* It seems strange to talk of what space "does" but modern simulations of it do just that:

> "*…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.

For the purposes of geometry, Euclid gave our space a structure many years ago as follows. First, he imagined a *point* with no dimensions. Then he extended that point continuously to create a *line,* that was again extended at right angles to give a *plane,* that was again extended to give a *cube.* This defined a *Cartesian space* with three orthogonal dimensions, where every point was represented by three real number coordinates (x, y, z).

War-gamers don't use Euclid's space because squares only allow four directions to attack an enemy but divide their maps into hexagons instead, to give more interaction *directions.* In general, a space requires:

1. *Dimensions*. That define the degrees of freedom needed to create it.
2. *Locations*. That define when two objects are "in the same place" and so interact.
3. *Directions.* That define the number of ways a point can interact with its neighbors.

Simulating space as a network isn't a new idea, e.g. in Wilson's networks a node is a volume of space and in Penrose's *spin networks* a node is a point event with two inputs and an output (Penrose, 1972). All these models, including loop quantum gravity (Smolin, 2001), cellular automata (Wolfram, 2002) and lattice simulations (Case, Rajan, & Shende, 2001) *map nodes to a Cartesian space,* so they all encounter the problem of *scalability*.

#### 2.2.4. Scalability

Berners-Lee called a *scalable* system one whose performance doesn't degrade as it expands however big it gets because growth increases demand and supply in tandem, so the system can grow forever (Berners-Lee, 2000). He designed the World Wide Web to be scalable and the Internet also began this way, as every new Internet Service Provider (ISP) increases both the demand and the processing to handle it. A scalable network has to distribute control but when the Internet began, pundits expected its lack of central control to result in chaos. It didn't collapse and the reason turned out to be *because* it had no central control. Computer science discovered that an infinity anywhere in a centralized network crashes it but distributed networks carry on despite a *local crash* - they degrade but don't collapse. Our brain neural network distributes control for the same reasons (Whitworth, 2008).

The performance of our space hasn't changed much over time, even after expanding for billions of years, so if space isn't nothing, it must be a scalable system. If our virtual space expands like the Internet, then adding nodes must increase both supply and demand, suggesting that space has local limits. The evidence agrees as:

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

We call the upper limit of what space can hold a black hole. It is in effect the bandwidth of space.

In general, *space as a* scalable *network suggests distributed control*.

In contrast, Cartesian coordinates require:

1. *A predefined maximum size:* Cartesian coordinate memory allocation requires a predefined size, so a point stored as (2,9,8) in a 9-unit cube must be stored as (002,009,008) in a 999-unit cube, and so takes up more memory.
2. *A zero-point origin*: A (0,0,0) point that is the absolute center of space.

A Cartesian space needs a predefined maximum size but our space has expanded for billions of years with no end in sight. If our space was Cartesian, its maximum size would have to be defined *before the first event,* to avoid a *Y2K problem*. Our Y2K problem arose because old computers stored years as two digits to save memory, so 1949 was stored as "49". The problem was that the year 2000 would be stored as "00" that was used for the year 1900. Changing all our databases to four-digit years meant that any programs accessing them might crash if not modified. That our space is still expanding without upgrade suggests that it can't be a Cartesian virtual space.

A Cartesian space also requires an origin point from which to expand. Since Hubble showed that every star and galaxy is receding from us, a Cartesian space implies that our Earth is that origin! Planet earth only began recently, so it can't be the Universe's origin. Our space is expanding *with no absolute center* so it can't be Cartesian.

In general, Cartesian coordinates work for small spaces but not for an expanding space as ours is.

### 2.2.5. A polar space

Cartesian space is so deeply ingrained in western thought that one might think it is the only way to describe a space but it isn't so. Euclid derived Cartesian coordinates by extending a point to a line, extending the line to a plane and then extending the plane to a volume. But instead of using straight lines, one can extend a point using rotations to derive *polar coordinates*[3].

Given a network, one can rotate a point to create a circle and then repeat. The first circle defines one-dimension, as every node has two neighbors giving left and right *directions* and the *distance* between two points is the number of link connections (Figure 2.3). The network *architecture*, or how the nodes connect, defines distance and direction as a node directly linked to another is "near" while another many links away is "far". The advantage of a circular dimension is that it is finite not potentially infinite and it does not have its zero point on itself.

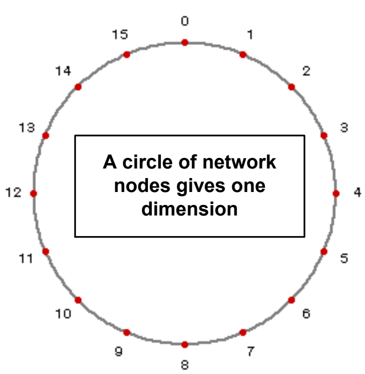


*Figure 2.3. A circle emulates one dimension*

So just as Euclid did for a line, the circle in Figure 2.3 can be *rotated* at right angles to give a two-dimensional sphere (Figure 2.4). A "Flatlander" confined to this surface would see a space that is:

1. *Finite.* Has finite number of points.
2. *Unbounded.* Moving in any direction never ends.
3. *Has no center.* No point on the sphere surface is the center.
4. *Approximately flat.* If the sphere is large enough.
5. *Simply connected.* A mathematical term that means any loop on it can shrink to a point.

In other words, this surface performs just like our space but with only two dimensions.

[3] Cartesian coordinates are represented by (x, y, z) values, but polar coordinates are represented by (r, θ, φ), where r is the radius from a fixed point in the angular directions theta and phi. Both systems need a (0,0,0) point.

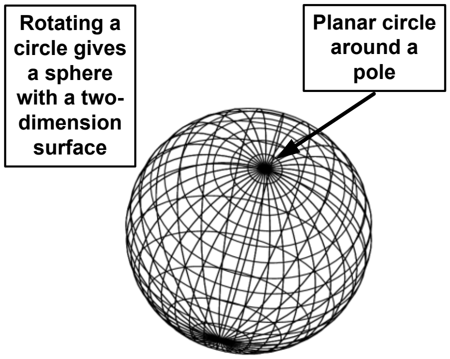


*Figure 2.4. A sphere surface emulates two dimensions*

Now just as rotating a circle gives a sphere with a two-dimensional surface, so rotating a sphere gives a *hypersphere* with a surface of three dimensions (Figure 2.5). A hypersphere is what you get by rotating a sphere just as a sphere is what you get by rotating a circle and in mathematics, a hypersphere surface has three dimensions just as a sphere surface has two. Centuries earlier, the mathematician Riemann speculated that our space was a hypersphere *surface* because such a surface is unbounded, simply connected and three-dimensional just as our space is. The logic is even more convincing today, when Einstein argues that space curves like a surface and cosmology says it expands everywhere at once like a balloon surface. Logically, our 3D space could easily be a surface in 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.*" (P. Davies, 2006) p45

If our space is a hypersphere *surface* within a four-dimensional quantum network, why then does space appear flat not curved? The simple answer is that the surface of a hypersphere bubble that has expanded for over 14 billion years would seem flat to us.

| | **Circle** (rotated point) | **Sphere** (rotated circle) | **Hyper-sphere** (rotated sphere) |
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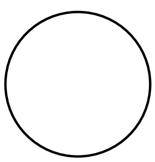
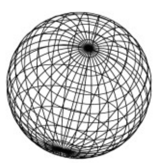
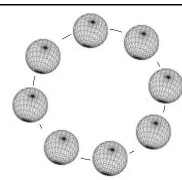
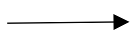
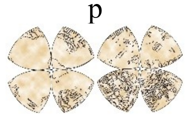
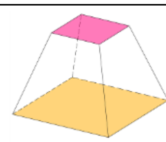
| ***Shape*** |  |  |  |
| ***Surface*** |  *A 1D line* | p  A 2D sheet |  A 3D space |

*Figure 2.5. A hypersphere has a three-dimensional surface*

### 2.2.6. Polar coordinates

A Cartesian space expands from a zero-point within it but a polar space doesn't. If one blows up a balloon, its surface expands everywhere at once, not from a point on the surface. The physics conclusion that space is expanding "*everywhere at once*", not from a fixed point in it, suggests that any simulation of it is polar not Cartesian. If the earth was flat then Cartesian coordinates would work but it turned out to be a sphere surface so we use longitudes and latitudes instead, which are polar coordinates. The north and south poles define the axis around which the earth rotates.

The nature of a circle is that its start point is arbitrary so any point can begin it. The axis chosen to turn a circle into a sphere is also arbitrary - rotating a circle on any axis through its center creates *the same sphere,* so the *poles* of the generated sphere are also arbitrary - any opposite circle nodes could be poles of the sphere (Figure 2.4). The same logic applies to a hypersphere, so if our space is a three-dimensional surface generated by rotation, how it happens is arbitrary.

Now add that this all occurs on a network. We know that our space is isotropic or uniform in all directions. If space was an object like the earth, it might rotate a certain way but it isn't a physical "thing" as there is no physical ether. Space as a polar simulation raises the question of what rotations generate it? The quantum network seems to do what quantum reality always does – take every option – but how could it do this?

If the sphere in Figure 2.4 came from fixed network rotations, it would have fixed poles, which is asymmetric. Every line is a connection on a network, so the poles would have more connections as shown in Figure 2.4 and the result wouldn't be a uniform space. Computer science however reveals that a network can easily alter its links, as our cell phone networks routinely change their connections to improve efficiency as the load changes. If the quantum network does the same, each node can *locally configure* its own links as if it were an axis pole. In other words, if control is distributed, each node can "paint" its own polar coordinates, setting its connections as if it were a rotation axis. This approach doesn't allow an objective view of space but as will be seen, our world has no need for that because as Einstein concluded, every object in our universe "*has its own space*".

A network that *distributes* control lets every node choose its neighbors as if it were the center of all space. Each gets a slightly different view but that doesn't matter because every view is equivalent. Each node of space decides itself which nodes are neighbors, just as a web designer can decide which pages a web page links to. In a distributed network, *polar coordinates allow a relative space where every node is the center of its own frame of reference*.

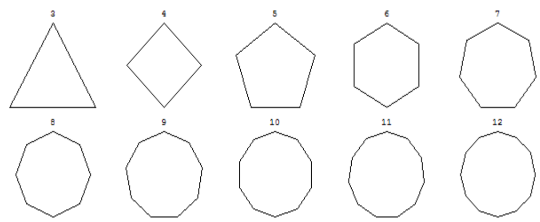


*Figure 2.6. N-circle rotations, N = 3-12*

#### 2.2.7. The density of space

Space generated by a network will have a *density* based on the number of links each node has to others. In the polar space derivation, this density is the number of steps in the rotations that create the space. A discrete rotation can have any number of steps, so if a perfect circle has infinite steps, a triangle is a "3-circle", a square a "4-circle", a pentagon a "5-circle" and so on (Figure 2.6). These N-circles approximate an ideal circle as N increases. It might seem that more rotation steps are better but wargamers and online games don't use octagons because they don't *"fill"* a flat surface, as side-by-side octagons leave gaps. Squares fill the board but only give four interaction directions so wargamers prefer hexagons as they both fill the board and give six interaction directions.

If the quantum network emulating space is dense, each point will have many connection directions but a large N-circle can't fill a Euclidean space perfectly. Does this exclude it from emulating our space? For example, not all paths in such a space would be reversible, so following a route taken in reverse may not return to the exact same node, though it would be a true vicinity. In essence, a discrete space based on polar coordinates will have "holes" in it, so billiard ball point particles could pass right through each other!

This might seem to disqualify a space based on discrete rotations but entities in our world are described by quantum probability clouds not billiard balls. When quantum entities "collide" they overlap over an area, so a space with a few holes in it doesn't matter. *That quantum entities exist as quantum probability clouds avoids the problems of N-circle space.* Since a polar space must have a finite number of directions for any quantum event, quantum realism predicts that direction, like length, is quantized, so there will be a minimum *Planck angle*[4].

#### 2.2.8. Quantum space

If our space is a surface *contained* within a network, it is in effect a space within a larger space, which oddly enough isn't a new idea. In 1919, Kaluza successfully derived Maxwell's equations from relativity theory by expressing Einstein's equations in four dimensions. He essentially unified quantum theory and relativity but his discovery was ignored because a *physically real* extra dimension would make gravity vary as an inverse cube so the solar system would collapse. Kaluza's extra dimension was denied because it contradicted physical realism, so when mathematicians discovered that electromagnetism could be explained by complex numbers rotating into a fourth dimension, they called that dimension *imaginary*. This was then accepted because it didn't contradict physical realism.

Klein then tried to rescue Kaluza's extra dimension by saying it was *compactified,* curled up in a tiny circle so entering it returned you to the start but this was also seen as unlikely. Years later, when string theorists needed to explain the six extra dimensions their mathematics required, they suggested that space contains extra dimensions

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

curled up *within it.* But why would nature create extra dimensions that do nothing except make our equations work?

In contrast, a virtual reality that appears on a screen surface is contained in a space with an extra dimension. If our space is a three-dimensional surface, there must be another *non-physical dimension* as well as the three *physical dimensions* of the virtual reality. Unlike string theory, this dimension *extends at right angles* to our space rather than *curls up* within it. *Quantum space is the four-dimensional space that contains our three-dimensional space as a surface within it.* It implies an extra dimension that we can no more enter than a game avatar can leave its screen world to enter ours.

Physicists express this idea by saying that space is a *brane* in a higher-dimensional *bulk* and conclude that if the extra dimension of that bulk is *sequestered* from our space, the gravity problem that denied Kaluza's theory long ago can be avoided (Randall & Sundrum, 1999):

> "*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.*" (L. Randall, 2005) p52

If this higher dimensional space is quantum space, our space is a polar surface rather than a Cartesian "slice".

#### 2.2.9. Electromagnetism

Electromagnetism is the general term for what we call light, which is known to be a wave although Einstein found that it is also particle-like. The advantage of space as a surface is that it allows waves to travel upon it. In current physics, light is a transverse wave whose amplitude is said to be imaginary but space as a surface allows light to vibrate into quantum space. A transverse wave needs a surface to vibrate upon so since light can travel in the vacuum of space, it must also be a surface. If a pool top is sealed in concrete, no waves can travel on it because the water can't move up and down, so if our space is similarly "sealed", how can light move as a transverse wave? Light as a wave has to vibrate at right angles to its direction in space but it is sequestered from that dimension because a wave cannot leave the surface it vibrates upon.

Imagine a pond of water with waves on its surface - there is the movement of the waves and the movement of the water. The waves move across the surface but the water moves up and down transversely, hence a cork just bobs up and down as a wave passes. What moves horizontally is a *pattern of transverse displacements* not the water. Likewise, light is a pattern of electromagnetic displacements into quantum space that move in our space. As a light wave can't travel in the direction of its amplitude, the quantum dimension is indeed "imaginary" to us.

That we are sequestered from the quantum dimension doesn't mean it doesn't exist. If light waves arise from positive and negative displacements on a surface just as a water wave does, this requires a surface for them to vibrate upon and that surface is our space. The only question is, what moves when light moves? Current physics doesn't accept that this displacement is *real* but quantum realism does. It sees light as processing waves spreading a quantum process on a network. It is now proposed that this *quantum process* is a rotating circle of values at right angles to space, in what from now on is called a *transverse circle.*

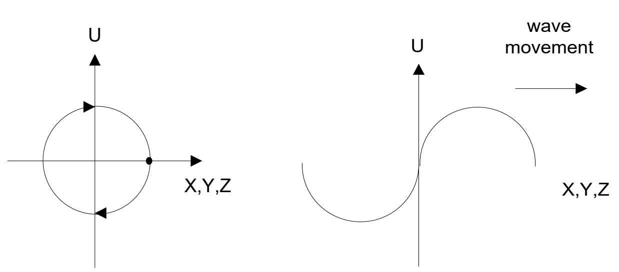



*Figure 2.7. Transverse processing as a. Space and b. Light*

To set a circle of values is efficient because the processing end begins another cycle. If quantum processing is like our processing, there are no half-cycles so a cycle must complete once begun. When this *quantum process* runs in one node, equal positive and negative displacements in the same cycle cancel out to give space. The same processing distributed over more nodes gives the wave pattern of light (Figure 2.7) as the next chapter explains.

If light waves are processing waves, the process is a rotation into an unseen dimension, exactly as the complex numbers that explain it assume. Schrödinger's equation describes an electron as a three-dimensional wave whose value at any point is set in an *imaginary dimension*. He called it a matter density wave because high values make matter more likely to exist there, but quantum waves act nothing like matter. Born called it a probability wave because its amplitude squared is the probability an entity exists there, but a probability is just a number. We expected the ultimate formula of reality to be physical but it isn't. The quantum waves that predict physical events aren't based on mass, momentum, velocity or any other physical property.

*That the unreal creates the real* makes no sense to physical realism but physicists who use complex numbers to predict physical events implicitly accept this. They also accept that an electron is a wave *and* a particle, that space is discrete in quantum theory *and* continuous in field theory, that the universe began at a big bang *and* is complete, and so on, until they call logic "philosophy" and give up on it. Quantum realism concludes that light is a quantum processing wave setting circular displacements transverse to the surface of our three-dimensional space.

### 2.2.10. Creating directions

On a flat surface, a *straight line* is the shortest distance between two points. The general term is *geodesic,* as on a curved surface like the earth, the shortest distance between the poles is a curved longitude. The shortest path between two points in all cases is a geodesic. Objects were said to move in straight lines by a property of their inherent mass called *inertia*. Newton showed that matter curved this path by the "force of gravity" then Einstein deduced that this "force" actually works by "curving" space to change the geodesic. Newton saw the earth as exerting a force to attract an apple but Einstein saw it bending space-time so the apple naturally "falls" to earth. He attributed object movement to matter's ability to alter space and time.

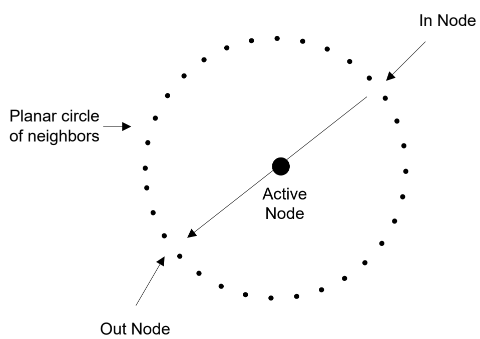



*Figure 2.8. A planar circle transfer*

If entities move by network transfers, light moves in straight lines by how the network transfers it, not by itself. Now suppose:

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

In network terms, a point in space is represented by the transfers available to a node, so the question of direction becomes "*How does a node pass on a photon*?" If a point in space is a quantum network node, all the ways it can receive a photon package from a neighbor and pass it on represent what it "does". The photon doesn't "decide" by itself where to go in empty space but is just passed on in a certain way by the network.

Every photon has a *polarization plane* at right angles to its transverse oscillation, so its transfer direction must be in the same plane. Let us call the set of neighbor transfers for any given plane a *planar circle*. Planar circles simplify the situation to an in-node/out-node transfer as shown in *Figure 2.8,* just as planar *anyons* simplify the quantum Hall effect (Collins, 2006).

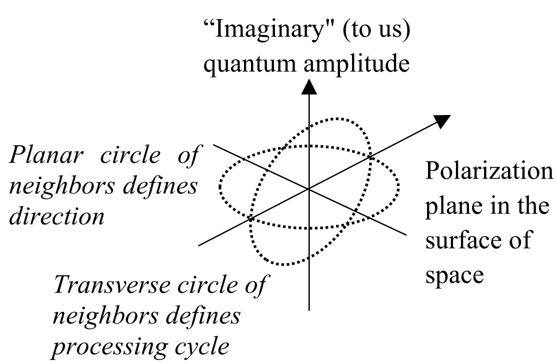



*Figure 2.9. Planar and transverse circles*

The shortest "distance" between two network nodes that we call a straight line is then the path with the fewest transfers. The path of fewest transfers is then the *fastest* path of a constantly expanding wave, Chapter 3 argues that quantum entities move in "straight lines" because that is the fastest network route. Network transfers also explain why the sun's gravity bends light around it, as in Chapter 5 the sun's mass redefines the fastest path by changing the network load differentially around it. In both cases, the direction taken is defined by the fastest transfer path not the choices of the entity.

*Figure 2.9* shows that for one node, a *planar circle* defines its transfer direction and a *transverse circle* defines its processing cycle. It is now proposed that just as planar circles define the directions of space, so processing transverse circles defines the passage of time.

## 2.3. TIME AS PROCESSING CYCLES

In physical realism, time is a dimension into which substantial objects extend themselves as they do in space. In quantum realism, objects are images generated, whose time arises from the processing cycles generating them. This section argues that time as processing cycles better explains time in our world than time as a dimension.

### 2.3.1. Time dilates

In an objective reality, time passes inevitably as matter exists by itself alone. In a virtual reality, time passes as processing cycles generate pixels. In Conway's Life simulation (Figure 2.10), pixel patterns are born, grow and die as if they were living entities. Their "lifetime" is measured in processing cycles just as atomic clocks measure our time by atomic cycles.

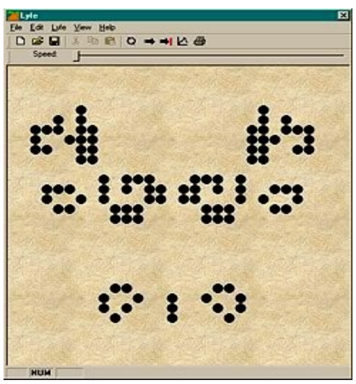


*Figure 2.10. Conway's Life*

If a pattern that repeats for twenty minutes of our time is run on a faster computer, it might only repeat for a few seconds so does its lifetime alter if the processing runs faster? It might seem so but its *virtual lifetime,* as measured in cycles, is the same because exactly the same virtual events occurred. It follows that virtual time depends only on the number of processing cycles completed regardless of the processing rate. It also follows that if two patterns that lived for the same number of processing cycles were run by different computers, one fast and one slow, they would last for different times to us even though their virtual lifetimes were the same.

Now consider Einstein's twin paradox, where one twin travels in space in a very fast rocket and returns a year later to find his brother is an old man of eighty. Neither twin was aware their time ran differently but one twin's life is nearly over while the other's is still beginning. Yet the eighty-year-old twin wasn't cheated of time, as he still got eighty years of heart beats and grandchildren to boot. The rocket twin only became aware that his brother's time had passed faster when he re-united with his twin to find that he was an old man. What relativity predicts in this case is exactly what we would expect if two patterns in Conway's Life were run at different processing rates!

When people first hear that time dilates they suspect a trick, that only *perceived time* changes, but it is *actual* time as measured by instruments that changes, so it's no trick. And it's not just theory, as short-lived particles live many times longer than usual when they are accelerated. Physical realism can't explain this, as an objective time shouldn't vary according to how fast one goes.

Time dilation occurs in games as all gamers know that the *screen frame-rate lags* in a big battle as the increased processing load makes events take longer. Game events slow down if the computer has a lot to do but the avatar's choices aren't affected. In other words, *game time* isn't affected by the screen slowdown. Likewise, for the rocket twins, it is as if the processing load that runs the life of one is greater so their time passes more slowly.

Relativity predicts that the faster one object moves relative to another, the more its time slows down. Quantum realism concludes that this is because increasing an object's speed increases the quantum processing load so the quantum cycles that define our time slow down. In the twin paradox, the rocket twin's speed increased the quantum workload leaving less processing available for his life, so he only aged a year. The twin on earth had no such load, so eighty years of his life cycled by in the usual way. Our virtual time "ticks" with each quantum cycle so what slows those cycles down also slows down our time. Time in our world behaves exactly like time in a virtual reality.

#### 2.3.2. Is time travel possible?

Physical realism assumes real objects that constantly exist in time and space, so if an object has left and right parts in the dimension of space, perhaps it has past and future "parts" in time. Minkowski interpreted Einstein's theory of relativity using a four-dimensional space-time matrix, so instead of existing at an (x, y, z) point in space, objects now exist at an (x, y, z, **t**) point in space-time, where **t** refers to *time*. An object now exists on a *world line* that extends in space *and* time, so one can talk of its "location" in time as one does for space and this enhanced idea of how objects self-exist has been generally accepted.

The Minkowski interpretation allows a *block theory of time,* where all past, present and future states exist in a "timeless time" (Barbour, 1999) p31 and a "time capsule" can be browsed like the pages of a book. That spacetime is the landscape that physical objects endure within implies that time travel is indeed possible. The equations of relativity work but equations are not reliable indicators of reality, as assuming all the mass of a body exists at its center of gravity works to calculate trajectories but no-one believes it is actually so. When physicists say that time travel is *"based on General Relativity*" they actually mean it is *based on Minkowski's interpretation* of relativity which is just a mathematical model.

Actually, no physical evidence at all supports time travel and assuming it creates impossible paradoxes. For example, Minkowski's interpretation predicts *closed time-like curves,* where an object's spacetime world line returns to its starting point, just as an object in space can curve back to where it began. This implies that a physical object can collide with itself, which is impossible. Other paradoxes include:

a. *The grandfather paradox:* A man who travels back in time to kill his grandfather couldn't be born and so he couldn't kill him. Reverse time travel allows an entity to interfere with its own cause, so that causality breaks down. It follows that one can have going back in time or causality but not both.

b. *The Marmite paradox:* I see forward in time to me having Marmite on toast for breakfast but next morning I decide not to, so I didn't see forward in time. If reality is a sequence of pre-existing states run forward, as block theory suggests, then *life is a movie already made* so there is no choice. It follows that one can have going forward in time or choice, but not both.

Such paradoxes suggest that spacetime is a mathematical artifact and so time travel is a fantasy. Physics turned Newton's canvas of space upon which objects were painted into a spacetime canvas, but it still doesn't work. After all, if we ever do travel in time, surely our first job would be to go back in time to stop the stupid things we are doing now! Like the multiverse fantasy, time travel is great science fiction but poor science because it denies both causality and choice.

#### 2.3.3. Specifying time

A time like ours must support the following properties:

1. *Sequence*. Events occur in a sequence.
2. *Causality*. Earlier events cause later events.
3. *Unpredictability.* Future events are not entirely predictable.
4. *Irreversibility.* Events cannot be reversed[5].

A virtual time that acts like ours must support sequence, causality, unpredictability and irreversibility.

*1. Sequence*

Sequence means that one event follows another, as in a movie. Movies achieve this by storing the sequence but storing quantum states in a database has two problems:

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

a) *Size*. The quantum states in our universe at any moment are innumerable and its cycle rate is unimaginable, so the storage needed is beyond belief.
b) *Inefficiency*. Why fill a database with *quantum events* that almost never happen? Why even store physical events, as no-one wants to read a "history" of World War II as atomic events? Or if only what is important is put on the record, how are the events to be stored selected[6]? If the physical world is a quantum simulation it does not make sense to store every event when one can just run the simulation again.

Storing quantum events isn't possible because quantum processing doesn't allow the static storage that physical computers use, as concluded earlier. But in quantum theory, quantum events do occur in sequence as the quantum wave evolves, so it may be that *the physical world the quantum world's solution to its storage problem* as a physical event is a *selection* from many quantum events. A physical event is in essence a report - we query quantum world to get the status update we call physical reality. This present report also contains the past, as neural memories exist *now* and dinosaur fossils exist *today* to tell us about what happened long ago. DNA "remembers" not just our ancestors but all life on earth. *Genes* (Dawkins, 1989), *memes* (Heylighen, Francis & Chielens, K., 2009) and *norms* (Whitworth & deMoor, 2003) survive by their generative power while that which lives for itself alone passes away. Regardless, the sequence of quantum wave evolution that quantum theory describes ensures that one physical event follows another, as quantum states:

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

*2. Causality*

Causality is the lawful connection between a sequence of physical events. We know that quantum reality is also lawful when quantum waves evolve in step-wise cycles, as processing does. These waves collapse to physical events only where quantum laws permit so if the quantum world is real, physical lawfulness follows from quantum lawfulness. If each quantum event causes the next lawfully, the physical events they ultimately cause will be the same. Physical causality thus arises from quantum causality, as described by quantum theory.

This doesn't imply that causality in time derives from *information* processing:

"*Past, present, and future are not properties of four-dimensional space-time but notions describing how individual IGUSs {information gathering and utilizing systems} process information.*" (Hartle, 2005) p101

It is correct to say that processing creates time but quantum processing can't be based on physical information, as McCabe observed, as information can't cause the physical events that cause it. In contrast, quantum processing isn't based on the physical states it generates, so it can generate the physical causality we see.

*3. Unpredictability*

A choice by definition has a known "before" and an unknown "after". Before there are many options but after there is only one, the choice result. In quantum theory, a photon approaches a screen as a *wave of options* that then collapses to the *point* where it physically hits. That point is *randomly chosen* from many options in a way that *no physical history can predict*. Even knowing every physically knowable thing, we can't predict quantum collapse because no prior physical "story" can explain why one option was chosen and no other. Quantum theory adds that *every* physical event involves a quantum collapse, so if our world is a machine, it is one with:

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

If quantum waves are processing waves, *quantum collapse is a process restart*. When many network nodes report an overload error, where the process restarts is a *server choice* made elsewhere. If the physical world is a virtual reality created by distributed quantum processing, quantum collapse is a server choice made outside the virtual reality so it is random to us. The result of quantum collapse is a physical event that *always* has a lawful causal history but also *always* contains an element of unpredictability.

[6] A human eye can detect one photon and one person can change the world, so one photon could change the world. As in chaos theory, little things can have big effects. If any photon is potentially "important", how to know which ones actually are?

*4. Irreversibility*

All the laws of physics are time reversible and reversing time doesn't break any laws of physics so if objects exist in a time dimension, *why can't we reverse time?* If quantum events create physical events, the question becomes *why is quantum collapse irreversible?* Physics has no answer but in computing, a node reboot is irreversible. Rebooting a computer restarts its processing from scratch, so any ongoing work is lost - unless you saved it! Processing is always sequential, as one step leads to the next, but one can't undo a reboot because the restart loses the previous event sequence. The sequence before the reboot is gone forever and the same is true when a quantum node reboots. Physical events are irreversible because quantum collapse as a successful node reboot is irreversible. *Quantum collapse creates the arrow of time.*

Quantum processing spreading down every network path until a node reboot restarts it in a physical event gives a time that is sequential, causal, unpredictable and irreversible, just like ours.

#### 2.3.4. Reality is here now

To Newton, time as the universal stream that carried all before it was the dimension in which all change occurs so time itself shouldn't also change, but Einstein showed that it did. How can a time that defines all change be itself subject to change? In calculus, a time change would be *dt/dt* which is a constant, so that time itself changes is impossible. That our time actually does change has led some physicists to suspect 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.

We conceive a dimension of time extending from past to future but the past is only known from its present effects and the future is unknown until it occurs. We deduce the past and predict the future from the present so all we really have is "now". We infer the universe from the light that hits the earth but again we only really have "here". We can imagine a past and future but *all we know for sure is that there is a here and a now*.

From the here and now we infer that time and space are dimensions but if the physical world is virtual, they are virtual too. Quantum realism suggests that our space is simulated by three orthogonal rotations on a network and our time is simulated by processing cycles in another orthogonal rotation. If so, time and space are results not causes and that is why our space can contract and our time can dilate as relativity experiments confirm. To create our time and space, *the quantum network only needs to create the here and now and we infer the rest*.

The quantum network needs four degrees of freedom, to simulate three directions of space and one of time. These degrees of freedom are equivalent, so it doesn't matter which create space or time, suggesting that there were initially four equal dimensions until the creation event broke that symmetry by causing *one of four equivalent dimensions to become time and the rest to become space* (S. W. Hawking & Hartle, 1983). But if four dimensions separated into three of space and one of time, *what were they dimensions of?* Physics has no abstract dimensionality that can separate into space or time but the degrees of freedom of a quantum network can do this.

Quantum realism has no time dimension, only network cycles with a time byproduct. It has no space dimension, only network transfers whose number and direction imply space. For a quantum network to create time that passes and space that extends requires only the here and now. The implication is that physical reality is an observer-observed interaction where quantum reality provides both the observer and the observed. Time then passes because every photon we observe had to complete a definite number of cycles to reach us and distance extends because it also had to complete a definite number of network transfers.

Relativity confirms that every object has its own spatial frame of reference and its own relative clock. This implies not only a "*Physics of Now*" (Hartle, 2005) p101, with no past, future or time travel, but also a "*Physics of Here*" that remains even as we move. *Quantum realism only requires an ever-present here and an eternal now.*

### 2.4. IMPLICATIONS

That our space and time are virtual has implications for physics.

#### 2.4.1. Space is a surface

In 1929, the astronomer Hubble concluded that all the galaxies were expanding away from us, leading science to conclude that the universe is physically expanding, but it seems to be doing so *everywhere at once* not just at its edges. If space is expanding "out", why is light from ancient times after the big bang still all around us today as cosmic background radiation? If space is expanding, what is it expanding into? And if space is something not nothing, where does new space come from? A physics based on physical realism struggles to answer such questions.

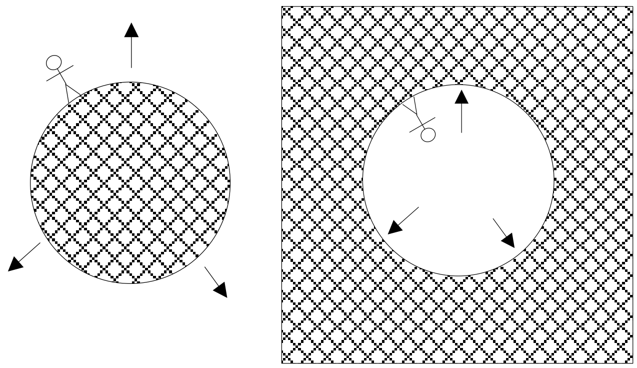

*Figure 2.11. Big bang vs. big bubble*

Quantum realism suggests that space is the *surface* of an expanding hypersphere (2.2.5). One might think that we are on the *outside* of that sphere but it makes more sense to be on its *inside*. Our space is then the *inner surface* of a big bubble in the fabric of reality not the *outer surface* of a big bang exploding into nothing (Figure 2.11). Space then has no center or edge like the inner surface of a blown-up balloon. It also expands everywhere at once as new space as added from the quantum bulk. The waves that move upon it in any direction wrap around, so ancient light wrapped around to end up everywhere, including all around earth. This answers questions like:

1. *What is space expanding into?* It is expanding into the *quantum bulk.*
2. *Where is space expanding?* Everywhere, as the bulk fills "gaps" that arise everywhere.
3. *Where does new space come from?* From the quantum bulk that contains our bubble.
4. *Are we expanding too?* No, existing matter isn't affected as new space is added.

In the next chapter, space as a surface lets light vibrate upon it, even in "empty" space.

#### 2.4.2. Big bang vs. little rip

When science found that all the galaxies were expanding away from us, it wasn't hard to calculate back to a moment in time and a point in space when our universe began. *Big bang* theory is that over 14 billion years ago, all the matter of the universe existed at a point *singularity* that then exploded out to create what we see today, but this simple extrapolation from now requires several miracles for it to be true.

The first miracle, as noted earlier, is that our universe of something had to be created from nothing. The second is that all the matter of the universe had to exist at a point singularity of infinite matter density. This is a miracle because in current physics, matter at that density would immediately collapse into a black hole from which nothing could emerge, so the universe would be stillborn. To avoid this, Guth proposed inflation theory (Guth, 1998), that *an immense anti-gravity field appeared from nowhere to expand the universe faster than light for* $10^{-32}$ *seconds*. This solved the black hole problem but what then stopped the inflation? Solving this needed another miracle, that the anti-gravity field then suddenly vanished, for no known reason, to play no further part in the universe.

The old *creation story* that God made the universe is now replaced by the story that nothing made everything at a point of infinite density that expanded faster than light by a magical force that then disappeared forever, leaving the universe to sedately evolve into the galaxies, stars and us. Given three miracles, the theory works, but a theory that replaces one miracle by three isn't a very convincing story.

Quantum realism proposes that our universe came from a primal reality that existed before it began, so it avoids the "*something from nothing"* miracle by stating that the physical world is a virtual reality.

It then proposes that like every virtual reality, our universe "booted up". When a Windows computer boots up, it first loads a tiny *CMOS* program that then loads a *kernel* program that then loads a bigger *BIOS* that finally loads the full Windows operating system. It is a step-wise process not an all-at-once process, so it is proposed that the first event created *one photon in one unit of space.* Booting up a computer isn't booting up a universe, but applying the same principle of starting small avoids the *singularity miracle* because one photon isn't a universe.

How can a virtual photon just "appear" on a quantum network? In computing, a *client-server* relation is where a network server gives its processing to clients, as when a *server* runs many *terminals,* each just a keyboard and screen connected to a network. Pressing a keyboard key sends a request to the *server* to send the right letter to the *client* screen. One server can run many terminals because it transfers processing much faster than clients run that processing. Even if client terminal users type as fast as possible, in-between each keystroke the server can handle hundreds of other people typing. The next chapter explains how a photon's quantum wave spreads as a *client-server relation* but for now, note that the sudden appearance of a photon on a network doesn't require a "*something from nothing"* miracle, as the server is just another network node. And a universe that began as one photon avoids the singularity miracle, as what initially exists physically is just a tiny seed of the universe to come.

If the first event was when one node of the quantum network gave its processing to other nodes, how did the rest of the universe arise? Creating one photon also created a "hole" in the quantum network that began space. As the first space was tiny, the first photon had a very short wavelength and so a very high energy. Current physics extends the electromagnetic spectrum indefinitely but a digital network has a minimum wavelength, so light has a maximum energy. One photon in one unit of space implies an *extreme photon* of maximum energy. It is then reasonable that putting a white-hot photon on the quantum network triggered other nodes to do the same, giving the *chain reaction* that physics calls inflation. A tiny "injury" to the quantum fabric quickly became huge, just as a pinprick can quickly rip a taught fabric apart.

Inflation as the quantum network "breaking apart" into servers and clients to create all the processing needed for a virtual universe then occurred faster than the speed of light because this "ripping" occurred at the *server rate* not the *client rate*. This avoids the need for a *massive anti-gravity field from nowhere to expand the universe in a faster-than-light miracle*. In this view, the initial plasma was:

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

What then stopped inflation from continuing forever? If inflation created space as well as photons, each step of the chain reaction created not only a unit of light but also a unit of space. Adding space increased the wavelength of light, diluting its energy, so cosmic background radiation that was white-hot at the dawn of time is now cold. The photon chain reaction grew exponentially but a hypersphere surface grows as a cubic function and a cubic growth will overpower exponential growth if the resolution is quick (Figure 2.12) as by the evidence inflation[7] was. This then avoids the *miracle of a massive anti-gravity field disappearing forever*.

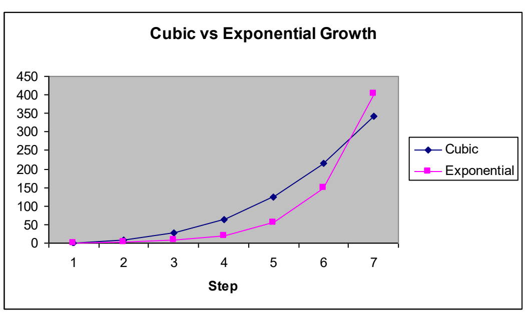


*Figure 2.12. Cubic vs. exponential growth.*

*That the physical world is a virtual reality makes this theory possible,* as a virtual reality can be created from nothing in itself, it can initially boot-up very small and it can be contained in a virtual space that expands. In science, one assumption followed by logic is simpler than three different ones followed by logic.

*Little rip theory* is that the first event created one photon in one volume of space that started the faster-than-light chain reaction that physics calls inflation but space expanded at each step to cause the chain reaction to stop, but not before it made our finite universe. Space then continued to expand to reduce the energy to levels suitable for life. It follows that the expansion of space isn't just an oddity of physics as without it, life couldn't have evolved. It also follows that the creation of our universe was a once only event that hasn't repeated since (J.

[7] 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.

B. Davies, 1979). Galaxies have come and gone but since inflation, *the quantum processing that generates the universe has remained constant*.

In conclusion, the "big bang" wasn't big, at first anyway, nor was it a "bang", as before the first event there was no space to expand into. It was *a little rip in the fabric of reality* that cascaded to create the quantum processing of our universe until the expansion of space "healed" it. The real miracle is that not only did a primal reality create everything we see today as a virtual reality but that continues to do so today. *The creation of our universe is an ongoing process not a one-shot event that happened long ago*.

#### 2.4.3. Losing transfers

When network nodes transfer data they must ensure that what is sent is received, as if one node sends two data packages and the receiver only gets one, the second is lost *forever*. Losing a data transfer like that in SimCity might cause an object in it to suddenly disappear for no reason. If our world did that, we would notice! Our universe has run for billions of years with no evidence that even a single photon has been lost, so if it is a network-based virtual reality, it must have some way to avoid transfer losses.

Our networks avoid transfer losses by transfer rules like the Internet hypertext transfer protocol or *http*. Such rules include:

1. *Locking*. Lock a file for exclusive access before the transfer.

2. *Clock rate*. Set a common clock rate for transfers.

3. *Buffers*. Use memory buffers to store transfer overloads.

*Locking*. My computer stores this chapter as a file on disk and if I load it into a word-processor to change it, the system "locks" it exclusively. If I try to edit the same document a second time, it says it is "in use" and won't let me. Otherwise, if I edit the same document twice, the last save would overwrite the changes of the first, which are lost. Yet locking allows the *transfer deadlock* case in Figure 2.13, where node A waits 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 encounter "dead" areas of space, which we do not. Another way is needed.

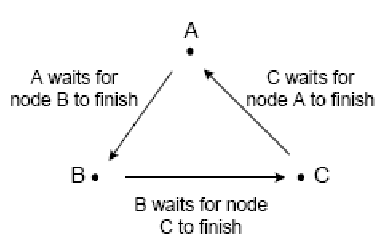


*Figure 2.13. Transfer deadlock*

*Clock rate*. Motherboards avoid the double-send of locking by using a common clock rate. When a *fast* central processing unit (CPU) fetches data into a *slow* register, it must wait for it to happen. Waiting too long wastes CPU cycles but using the register too soon gives garbage from the last event. The CPU can't "look" to see if the data is there because that is another command that needs another register that would also need checking! So it uses the *clock rate* to define the cycles to wait for any task to complete. The CPU gives its command then waits that many cycles before using the register. The clock rate is usually set at the speed of the slowest component plus some slack, so one can *over-clock* a computer by reducing the manufacturer's default wait cycles to make it run faster, until at some point this gives errors. This requires a system with a central clock but we know that our universe doesn't have a common time. A virtual universe that ran to a central clock would cycle at the rate of its slowest node, say a black hole, which would be massively inefficient. Again, another way is needed.

*Buffers.* Early networks avoided transfer losses by protocols like *polling* that route every event through a central node but centralization was soon found to be inefficient. Protocols like Ethernet[8] improved efficiency tenfold by *distributing* control, letting nodes run at their own rate and using buffers to handle overloads, so if a node is busy when another transmits, the data is stored in a buffer until it is free. Buffers let fast devices work with slow ones, so if a computer (fast device) sends a document to a printer (slow device), it goes to a *printer buffer* that feeds the

[8] 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*.

printer in slow time. This lets you carry on using your computer while the document prints. Yet planning is needed, as big buffers can waste memory while small buffers can overload. The Internet fits buffer size to load, with big buffers for backbone servers like New York and little buffers for backwaters like New Zealand. If our universe is virtual, stars are like "big cities" while empty space is like a backwater where not much happens. To use buffers, the network would have to know in advance where stars occur which is unlikely, and allocating even small buffers to the vastness of space would waste memory. Again, another way is needed.

#### 2.4.4.The pass-it-on protocol

How can a quantum network conserve photon transfers? Our universe as a virtual output can't use a common clock as it has no common time, it can't use fixed buffers as stars and galaxies occur unpredictably and transfer locks would lead to dead areas that we don't observe.

When a pebble falls into a still pool, it creates a wave of ripples that spread on its surface. This *physical wave* begins when the pebble "dents" the pool surface to begin an up-down motion that spreads out in all directions as ripples. Now imagine "dropping" a photon process on the quantum network where by its nature it also spreads out in all directions as quantum wave ripples. A quantum wave isn't physical but the dynamics are the same. The photon initiates a displacement where it begins that spreads by the dynamic nature of quantum processing.

Any node involved in this *processing wave* now has two things to do each cycle: *run* the process in the node and *pass it on* to its neighbors. For a network, this raises a question irrelevant to physical waves, namely "*Which happens first?*" One might expect a node to run the photon process first then pass it to its neighbors but this could give transfer losses for asynchronous nodes so it is better to first pass the processing on then run what it receives.

If nodes transferring photon processing waited for destination nodes to finish their cycle, the speed of light might vary for the same route, which it doesn't. That light doesn't wait implies that nodes immediately receive any transfer as an *interrupt*. In computing, an interrupt is a signal that is always received whatever a processor is doing, e.g. in Windows, pressing Ctrl-Alt-Del keys simultaneously generates a CPU interrupt that runs the Task Manager.

The quantum network *pass-it-on protocol* is that each node *first* passes on its current process as an interrupt *then* runs any processing it received. The interrupt may "lose" a cycle but transfers are never lost because interrupting a processing cycle before it finishes isn't a problem but losing transfers is. That light is immediately passed on makes the speed of light constant and that quantum packages are always passed on avoids transfer losses.

Yet interrupts could cumulate if a circle of nodes each interrupted the next before it finishes its cycle, giving an endless interrupt loop where no processing runs at all, like the deadlock loop earlier. Fortunately, expanding space adds new nodes not just at some "edge" but everywhere. A new node that enters our space has no processing to pass on for its first cycle and receives only, which stops any pass-it-on interrupt build-up. Nodes that accept processing but pass none on prevent pass-it-on interrupts from cumulating.

Since the speed of light is constant, light spreading throughout the universe acts to synchronize the network despite it being decentralized. The effect isn't perfect but that light transfers everywhere keeps nodes in synchrony.

In this protocol, nothing ever waits so there is no need for buffers, perfect synchrony isn't required so there is no need for a central clock and one step-transfers avoid a two-step transfer deadlock. The quantum network is decentralized to increase performance and reliability but no transfers are lost. Light moves on every cycle, no transfers are lost, and adding new space prevents infinite pass-it-on interrupts from building up.

#### 2.4.5. Empty space is full

In physical realism, matter objects are real but the space between them isn't, so it is just nothing and nothing, by definition, should *do nothing*. Yet light waves travel in even the purest vacuum so space doesn't do nothing, *it hosts light*. If light waves travel in a vacuum, space as the *medium* of those waves can't do nothing. Likewise, that gravitational waves travel in space implies it is something with the sort of elasticity to allow that.

A space of nothing should have no properties but space enables the property of *distance*, as if there is *nothing* between the earth and the moon, why aren't they touching? That space allows the property of distance even without matter present suggests again that it isn't nothing.

If empty space was really empty it would have no energy but the evidence is that:

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

That *empty space isn't empty* (Cole, 2001) is illustrated by *The Casimir effect.* Two uncharged flat plates held close together in a vacuum register a force pushing them together. Current physics attributes this *vacuum pressure* to virtual particles that pop out of the "empty" space around the plates but how can emptiness create particles? Quantum theory allows the Casimir effect because it says that a point of space can't constantly have zero energy. The dynamic nature of space causes the *energy of the vacuum* but a truly empty space couldn't have this property.

Martin Rees suggests how space could be something as follows:

"*Empty space seems to be nothing to us. By analogy, water may seem to be nothing to a fish – it's what's left when you take away all the other things floating in the sea.*"

He suggests that space is something although it seems nothing to us because it is a constant background. Empty space isn't a *physical thing* but as Einstein said it has to be "something" for relativity to work:

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

And quantum theory itself implies some sort of *quantum 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.

The current answer to this conundrum, that space is something and nothing, is *field theory*. In the case of light, space hosts an electromagnetic field that rotates into an imaginary fourth dimension as described by Maxwell's equations. The "nothing" of space now hosts non-physical fields that cause physical effects but how does empty space do that? In physical realism, physical effects have physical causes but field theory's fields aren't physical any more than space is. That non-physical fields have physical effects works as long as no-one asks "*What is <u>really</u> going on?*" How can the "nothing" of space plus an imaginary field create the "something" of a physical force?

In quantum realism, empty space is the quantum network running a null process and matter is the same network running another process. The network shows nothing or something in the same way that a screen can show blank or an image. When the network presents as empty space, it runs a positive-negative null process that sums to zero. When it hosts light, a non-zero displacement moves across it, and when it hosts matter, that displacement remains at a point, as the following chapters explain in more detail.

Space as network null processing has a distance property so the earth doesn't touch the moon because there are null nodes in between. Space as the network doing nothing can also be that through which matter moves but how can empty space as null processing have energy? If empty space is null processing, why isn't the result all zeros?

The answer is that a null process is a positive-negative displacements that is only zero at the end of each cycle. On a *synchronized* network, all the nodes would be zero at the same time but the quantum network is asynchronous so that isn't so. Thanks to light, it is *mostly synchronous* but not perfectly as each node cycle runs independently, so all the nodes of empty space aren't zero at the same time. The quantum theory statement that points of space fluctuate in energy reflects the essential asynchrony of the quantum network. The points of space *average* zero over time but at any instant they aren't *simultaneously zero,* as quantum theory says. Like the static on a blank screen, space averages to nothing but isn't constantly so. The quantum network is the non-physical medium that Einstein suspected had to exist.

Newton saw space as like a tablecloth that presents the cutlery of objects but quantum theory sees dynamic states that only average to nothing. That space is more like what Wheeler called a *quantum foam* than a passive surface is evidenced by the Casimir effect but if empty space is "full" not empty, what is it full of? Physical realism has no answer but quantum realism says it is full of quantum processing.

When one looks through a window, one sees the view but not the glass transmitting it. One only sees the glass if it has imperfections, a frame around it, or if one can touch it. Now suppose the "glass" transmitting physical reality has no imperfections so it can't be seen, is all around so there is no frame, and it transmits matter as well so we can't touch it. The quantum network is like a perfect glass that flawlessly reveals the images of physical reality without showing itself. *It is the fullness that we call emptiness*.

## 2.5. REINVENTING PHYSICS

Modern physics is at a crossroads because while past equations like $E=mc^2$ were one-liners, the new equations of string theory fill pages, if not books. If science gathers knowledge from the tree of nature, the low-hanging fruit of single-line equations have all been picked. The era of equations is over so better tools like computer simulation are needed but while simple equations can be deduced from patterns in data, simulations need a valid model of what is being simulated. Current physics is stagnating because it chose the desert of physical realism over a future based on quantum realism.

### 2.5.1. The end of physics?

Over a century ago, physics left the safe haven of classical mechanics seeking a promised land that explained how light moved and gravity acted at a distance. Digging deep, physicists discovered relativity and quantum theory by imagining causes they couldn't see, like quantum waves, quantum collapse, time dilation and curved space. Equations that worked in non-physical ways led to the modern world of transistors and satellites but rather than exploring the non-physical further, physics settled down in the *semantic desert of physical realism,* a place where no new theories grow. Nothing grows in this place so *what puzzled Einstein and Feynman over fifty years ago still puzzles us today*.

Modern physics has now been stagnating for over fifty years. As the physicist Smolin explains, *The Trouble with Physics* (Smolin, 2006) is that it has given itself over to ungrounded theories that *can never be tested*. Trying to understand quantum reality has been abandoned so some busy themselves with books and TV shows to explain what they don't understand themselves while others rally the troops with papers on strings, multiverses and supersymmetry that are *Not Even Wrong* (Woit, 2007). *Even the weeds of error don't grow in this desert!*

Physicists, like a baker with no bread, now occupy themselves by selling novelties, writing scientific papers on white holes, eleven dimensions, time travel, closed time loops, WIMPs, wormholes, heavy sterile neutrinos, super-particles that hint at the next revolution in physics, but it never comes. In a recent New Scientist cover story, the authors speculate that *axiflavons* from a hypothetical *flavon* field will solve physics problems and conclude:

"*Its thrilling stuff, if for the moment it is only conjecture*", New Scientist, August, 2018, p31

But conjecture without evidence isn't science, as Hossenfelder explains:

"*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. Over and over again I have heard them justifying their mindless production of mathematical fiction as "healthy speculation" – entirely ignoring that this type of speculation has demonstrably not worked for decades and continues to not work. There is nothing healthy about this. It's sick science. And, embarrassingly enough, that's plain to see for everyone who does not work in the field*."

For decades now, physics "breakthroughs" have turned out to be mirages, with papers titles like:

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

In such writings, "may" is the operative word. The last fifty years of physics can be described as *maybe* WIMPS, *maybe* strings, *maybe* supersymmetry, *maybe* a multiverse, *maybe* time travel and so on. The fizz has gone out of physics so much that some despairingly suggest *The End of Physics* because:

"*… 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.*"

But how can the laws *we invent* prevent us from understanding reality? What held back physics in the nineteenth century was its claim to already know all the answers so is that we already know all the answers really a valid argument for the end of physics? What is stopping knowledge isn't nature but the dogma of physical realism.

Physics is wandering in the *desert of physical realism,* the naïve belief that we see all there is, and if it stays there, the next fifty years will be as barren as the last. It is looking for answers in the wrong place, like the man who looked for the keys he lost in the forest under a lamp post because "*The light is better here*." By denying quantum waves, physics abandoned humanity's greatest discovery, *that a non-physical quantum reality generates the physical world*.

Theories without evidence have no reality roots. No data supports string theory's $10^{500}$ variants but thousands of papers have been written on it. Instead of building castles in the air, why not start anew from the data ground? Quantum realism proposes reinventing physics *from the data ground-up*.

### 2.5.2. Grounded physics

When Europeans first visited China, they saw a society that made no sense to the bible, king and country culture they came from. Anthropologists eventually realized that concepts like "keeping face" only made sense in the context of that new culture. They had to understand Chinese society on its own terms not theirs. The scientific method used to learn new a cultural context is called grounded theory, which as the name implies, is to first gather ground-level data *then* theorize. Following this method, anthropologists visiting a new tribe first watch, listen and record, *then* form a theory to test next day and repeat until they understand the culture on its own terms. The skill of *letting the data speak* avoided colonial bias but seemed to reverse the usual method of science, until Kuhn noted that science has *two* phases (Kuhn, 1970):

1. *Paradigm growth:* Theory predicts new data.
2. *Paradigm shift:* Data implies a new theory.

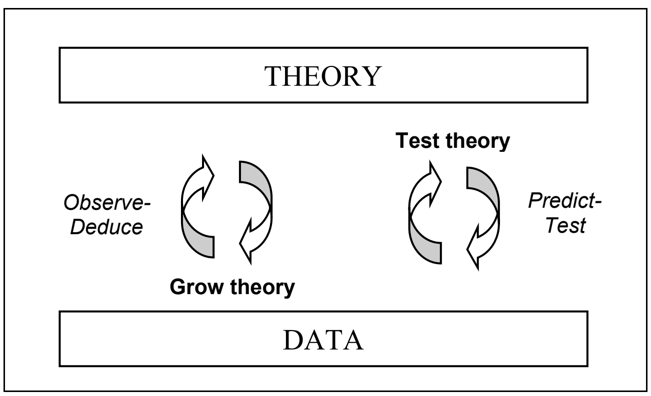


*Figure 2.14 Paradigm shifts grow theories*

In *paradigm growth,* theory predicts data and in *paradigm shift,* the data grows a new theory. The first is slow and steady, as water wears away rock, but the latter is often sudden, as an earthquake alters the land in a short time. The history of science is then that established theories rule until an intellectual earthquake raises a new theoretical landscape from the data ground.

Figure 2.14 shows that science, as a way of *connecting* data to theory, can work from theory to data by a *predict-test* method or from data to theory by an *observe-deduce* method. If current physics no longer predicts anything new, it is time *to grow a new theory from the ground up*.

The computer science version of grounded theory is *reverse engineering.* It is essentially to understand a new digital system by observing its outputs, form a model of the processing that could produce those outputs, then test the model by further interactions, and repeat until consistency is achieved. The aim of quantum realism to reverse engineer physical reality is thus essentially *grounded physics*.

The premise is that traditional physics approached quantum reality as colonials approached China, calling what didn't conform to its traditional culture imaginary. The culture of physical realism handed down from Aristotle is as embedded in physics as King and Country was in colonial societies. The arrogance in both cases is palpable, as physics dismisses what it doesn't understand just as colonials did. The quantum realism alternative is to understand quantum reality on its own terms, not dismiss it based on our physical tradition. *To take this step is not to abandon science but to embrace it*.

### 2.5.3. A new perspective

Quantum realism involves looking at reality in a new way, not as what we see but as what we can't see. Quantum waves literally can't be seen by our measuring devices but we can still reverse engineer them, as that is how quantum theory was invented in the first place. Many still don't *believe* in what they can't see but that is changing. If waves we can't see fill our phones with data we can, why can't a quantum world we can't see create the physical one we can?

One concern is that accepting quantum reality will lead to a God-theory that explains everything and predicts nothing but reverse engineering doesn't work that way as it assumes a *finite* processing source following the rules of computer science. Reverse engineering is an iterative scientific method based on testing and Chapter 4 gives a testable prediction that current physics denies - *that pure light can collide*.

Reverse engineering physical reality assumes quantum theory is a reality description and follows the facts. Doing this immediately explains some well-known physics facts:

1. *Quantum randomness occurs.* If the quantum collapse is a choice that occurs outside physical reality, this is no longer surprising.
2. *Complex numbers work*. If electromagnetism does rotate into another dimension, this is no longer surprising.
3. *Planck limits exist*. If our space and time are digital, this is no longer surprising.
4. *Feynman's sum over histories works*. If quantum entities do take every path, this is no longer surprising.
5. *Space curves in general relativity.* If our space is a 3D surface, this is no longer surprising.
6. *Time dilates in general relativity.* If our time is created by processing, this is no longer surprising.

Quantum realism implies that the equations of physics aren't fictional but literally true. If the equations of physics are good enough to use, why aren't they good enough to believe?

The *calculus* used throughout physics illustrates the case. It began as a thought experiment, like quantum theory, that infinitesimals "in the limit" predict physical reality and like quantum theory, it worked brilliantly. Physical realism decreed that it had to be just a theory but why not see it as a reality description? If space *actually does change* in infinitesimal pixel steps and time changes in indivisible cycles[9], Zeno's paradoxes are resolved. Calculus was only rejected as a reality description because physical continuity is a canon of orthodox physics.

*Quantum realism is a new perspective on reality based on applying a known method of science to the facts of physics*.

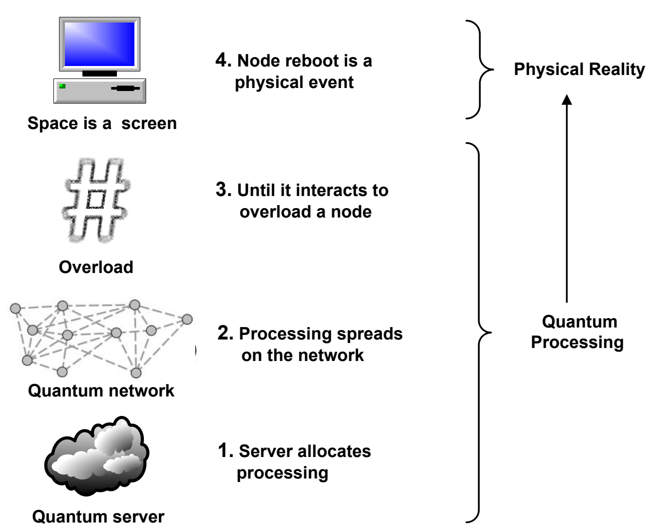


*Figure 2.15. Quantum processing gives physical reality*

### 2.5.4. The quantum model

Figure 2.15 summarizes the basic quantum model that the following chapters explain in more detail:

1. Quantum servers allocate processing
2. That spreads on the quantum network as waves
3. Until they interact to overload a node
4. That reboots in a physical event

[9] 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.

A photon is then a processing wave that spreads in all directions by node-to-node transfer until it overloads a node point in a physical event that causes it to restart again. Quantum waves as processing waves can *evolve* on a network, *superpose* when they overlap, *collide* when they overload a node, *collapse* when a node reboots and *entangle* if the restart merges the processing, as discussed later. Quantum waves as processing waves even explain relativity in Chapter 5. To reverse engineer the equations of physics only requires us to accept that a quantum processing engine *could* create the physical world as a virtual reality.

Last century, physics invented a tale of quantum waves spreading at light speed that collapsed instantly to a physical event when observed. It made no sense because no physical wave could do that but it worked brilliantly! *No-one noticed at the time that quantum theory could be describing processing waves on a network*.

In quantum theory, we must interact with reality to observe it, as Heisenberg's uncertainty principle implies that to observe a photon, we must change it and the symmetry of interactions implies that both parties observe. It follows that physical reality is like a painting that we can't see until we paint it, on a vast landscape where many others are doing the same. We only see our local here and now and from this deduce the universe, but it is hubris to assume that we are the only "painters". If our time and space are defined by the directions and speed that we paint, without that "painting", time and space as we know it would no longer exist.

Table 2.1 given next compares quantum and physical realism for space and time, so readers can decide for themselves which offers a better explanation of the facts.

*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:<br>a) Physical objects cause all physical events<br>b) Randomness is not possible<br>c) Replaying physical events is reloading reality<br>d) One day we will upload and reload ourselves | **Quantum realism**. Only the quantum world exists so:<br>a) Quantum processing causes all physical events<br>b) Randomness is possible<br>c) Replaying physical events is not reloading reality<br>d) Quantum reality can never be saved or reloaded |
| ***Space***. Is the "no-thing" between matter so it is:<br>a) *Empty*. Yet it hosts virtual particles<br>b) *Continuous*. Yet there is a Planck length<br>c) *Containing*. Space contains all things in itself<br>d) *Expanding*. But how can nothing expand?<br>e) *Absolute*. A cartesian space has an absolute center<br>f) *Doesn't mediate light*. So light is a wave of nothing<br>g) *Unlimited*. So the universe can exist at a singularity<br>h) *Always zero*. Which quantum theory denies | ***Space***. Is quantum null processing, so it is:<br>a) *Full*. Null processing just looks empty<br>b) *Discrete*. Hence there is a Planck length<br>c) *Contained*. Space is merely a 3D surface<br>d) *Expanding*. Into a larger quantum bulk<br>e) *Relative*. Each quantum node "paints" its own links<br>f) *Mediates light*. So light is a wave "on" space<br>g) *Limited*. The bandwidth of space is a black hole<br>h) *Averages zero*. As quantum nodes are asynchronous |
| ***Time***. Objects exist inevitably in time, so it is:<br>a. *Continuous*. Yet there is the Planck time limit<br>b. *Real*. Yet it slows down with object speed<br>c. *A dimension*. That objects can time-travel in?<br>d. *Reversible*. According to every law of physics | ***Time***. Time is based on quantum cycles, so it is:<br>a. *Discrete*. Planck time is one quantum cycle<br>b. *Virtual*. It slows down with processing load<br>c. *Not a dimension*. Time travel is impossible<br>d. *Irreversible*. As a physical event is a reboot |
| ***Directions***. Moving objects are self-directed so:<br>a. *A straight line* is a moving object property<br>b. *Gravity* "bends space" to alter straight line paths<br>c. *Angles*. Every angular direction is possible | ***Directions***. Moving objects are network transfers so:<br>a. *A straight line* is the fastest network transfer path<br>b. *Gravity* alters the fastest network transfer path<br>c. *Angles*. Are quantized for a quantum event |
| ***The big bang***. The universe began entire all at once:<br>a. *Cause*. Nothing at all, as the universe is all there is<br>b. *Start*. The physical universe started as an infinitely dense singularity at a dimensionless point<br>c. *Inflation*. A huge anti-gravity field from nowhere then expanded the singularity faster than light<br>d. *Inflation stopped*. After $10^{-32}$ of a second that field conveniently disappeared forever<br>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":<br>a. *Cause*. The previously existing quantum network<br>b. *Start*. The physical universe began when one photon was created in one unit of space<br>c. *Inflation*. The extreme energy of the first photon caused others to follow suit in a chain reaction<br>d. *Inflation stopped*. Inflation also generated space that diluted the first light to stop the chain reaction<br>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 copy of physical events replay reality? What is missing? (2.1.3)
3. If the universe is a virtual reality, what would be necessary to save and reload it? (2.1.3)
4. Can one copy a physical state? What about a physical event? What about a quantum state? (2.1.4)

5. How does quantum processing differ from the physical processing? Why is it so powerful? (2.1.5)
6. If the physical world is a virtual reality, what is the screen? What is its resolution and refresh rate? (2.2.1)
7. State Zeno's paradoxes. How does physics resolve them? How does quantum realism resolve them? (2.2.1)
8. Is space something or nothing? If nothing, what transmits light? If something, what is it? (2.2.2)
9. Would a network simulating our universe be centralized or distributed? Explain why. (2.2.4)
10. Why do polar dimensions explain our space better than Cartesian dimensions? (2.2.5)
11. How can space expand "everywhere at once", as physics says? (2.2.6)
12. What is the main problem of using a polar space? How is it resolved? (2.2.7)
13. Compare an extra dimension *curled up* in our space to one that *contains* our space. (2.2.8)
14. If reality has a fourth dimension, why can't we enter it? (2.2.8)
15. If light is a transverse wave, like a wave on a lake, on what surface is it vibrating? (2.2.9)
16. Traveling at near light speed slows down your time, so does this mean you live longer? (2.3.1)
17. Is there any evidence for time travel in physics? Why is time travel unlikely? (2.3.2)
18. Why can't quantum entities go back and forth in time? (2.3.3)
19. If three degrees of freedom of the quantum network represent space, what does the fourth represent? (2.3.4)
20. Why is cosmic background radiation from the early universe still all around us? (2.4.1)
21. What caused the initial inflation of the universe and what stopped it? (2.4.2)
22. What happens if a network data transfer fails? How do our systems avoid this? (2.4.3)
23. How could a quantum network avoid transfer losses? (2.4.4)
24. Is the vacuum of space empty or full? If full, what is it full of? (2.4.5)
25. Why is theoretical physics no longer advancing? (2.5.1)
26. What can science do when a theory no longer generates new knowledge? (2.5.2)
27. Do the equations of quantum theory describe what is imaginary or what is real? Justify. (2.5.3)
28. If the equations of quantum theory describe nothing, why do they predict physical events? (2.5.3)
29. Is quantum realism a "God theory"? Why or why not? (2.5.3)
30. If quantum waves are processing waves, how does that change our understanding of quantum theory? (2.5.4)

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