Quantum Realism

Chapter 2. Simulating Space and Time[1]

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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

2.1. INTRODUCTION

2.1.1. Overview

This chapter asks whether a virtual space-time could appear to those within it as our space-time does to us. It wonders if space is a three dimensional screen and time passes according to its refresh cycle rate.

2.1.2. A processing network

In computer simulations, *programs* direct *processing* to create the *pixels* we see. That the physical world arises in this way is a radical idea, but it is not new:

1. *Fredkin.* That the physical world is a processing 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.* Suggests 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 at a deep level, everything is information.
4. *D'Espagnat*. Proposes a "*veiled reality*", beyond time, space, matter and energy (D'Espagnat, 1995).
5. *Tegmark* (2007). Proposes that: "*There exists an external physical reality completely independent of us humans*"
6. *Campbell.* Proposes that "*The big computer*" runs everything (Campbell, 2003).
7. *Barbour*. Visualizes quantum waves as arising from an underlying landscape, where "*The mists come and go, changing constantly over a landscape that itself never changes*" (Barbour, 1999) p230.

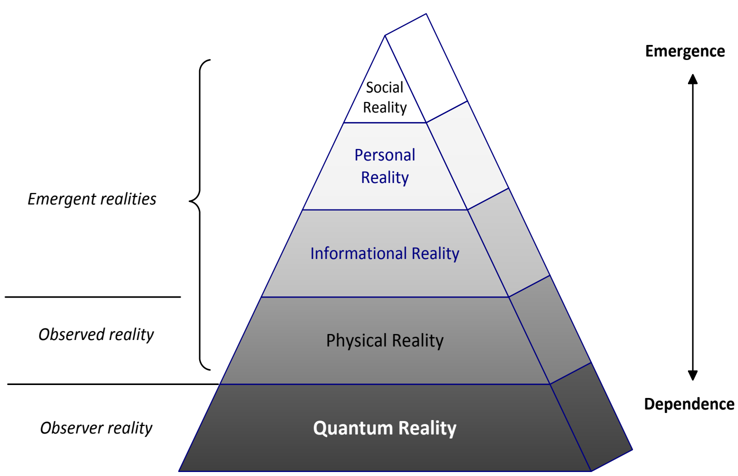

Figure 2.1. Physical reality emerges from a quantum reality

In this view, quantum processing is Fredkin's *Other*, Wilczek's *Grid* and how Wheeler's physical *It* comes from *Bit*.

[1] First published as: Whitworth, B., 2010, Simulating space and time, Prespacetime Journal, March, Vol. 1, Issue 2, Page 218-243, then at http://arxiv.org/abs/1011.5499 . Latest versions at: Chapter1, Chapter2, Chapter3 and Chapter4.

D'Espagnat's *veiled reality* is a quantum world hidden from us by the physical images it generates. If an external reality computes the physical world as Tegmark theorizes, then Campbell's big computer is feasible, and Barbour's quantum mists could be patterns on a processing landscape. In quantum realism, the physical world draws its existence from a *processing grid* just as a city draws its energy from a power grid.

The idea is that a primal *quantum reality* generates physical reality as a program creates pixels. So physical systems *emerge* from a fundamental quantum reality, just as the informational, semantic and social systems of other sciences emerge from physical reality (Figure 2.1). That physics is just another "view" of reality, no different from any other science, isn't popular in physics, but this chapter now suggests that it fits the facts.

2.2. DIGITIZING SPACE-TIME

2.2.1. Dynamic information (processing)

To understand whether information could create our world, it is necessary to understand what information is.

What is information?

Modern information theory began with Shannon and Weaver, who defined information as the number of options in a *choice*[2] expressed as a power of two (Shannon & Weaver, 1949). So two options are one bit, 256 options are 8 bits (one byte) and one option, which is no choice at all, is zero bits. *Processing* was then defined as the changing of information, i.e. making a new choice.

We take a book to contain information, but its text is fixed in one physical way, which is *one physical choice*, that by the definition is *zero* information. This may seem wrong but hieroglyphics that one can't decipher do indeed contain no information. A book only gives information when a reader's choices create it, and the information result *depends entirely on the decoding process* e.g. reading every 10th letter of a book, as in a secret code, gives both a different message and a different amount of information.

Information as we understand it requires a *decoding context*, e.g. one electronic pulse sent down a wire is one information bit, but if it represents ASCII value "1" it is one byte, and as the first word in a dictionary, say Aardvark, it is many bytes. The information "in" a physical message isn't actually in it, because it is undefined if the decoding context is unknown. How else can data compression put more information in same physical signal[3]? If how to read it is unknown, the information in a signal is undefined, e.g. we know the "letters" of the human genome but until we know how they interact, we are still learning the genetic "language". Only when a writer and reader use the same encoding-decoding processes can they agree on the information in a physical message.

Static information

Let *static information* be information obtained from a physical symbol by a known decoding process, like the English language, and *dynamic information* be the choosing itself, i.e. processing. So *writing* a book involves dynamic information, as one can write it in many ways, as does *reading* it, as one can read it in many ways, but the book itself, being just one way and no other, has static information but no dynamic information.

A physical world based on static information could be saved, restored, copied, duplicated, downloaded and uploaded, given an external observer context to encode/decode it. A physical world based on static data would need a designer to "write" it across time and space. So as McCabe argues:

> *"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).

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

[3] Which it does by more efficient encoding/decoding.

A physical world of static information would imply a context, which is impossible if it is all there is, and implies an arbitrary designer if it isn't, but the dynamic act of processing itself has no such limitation. In this model, non-physical quantum processing dynamically outputs the physical world as a series of static states.

Reality can't be saved, downloaded or uploaded

We save, download and upload static data but dynamic processing doesn't work that way. To understand this, recall that Einstein derived relativity by imagining he was surfing a light wave "frozen" in space and time, but then concluded that this was impossible, and changed his ideas of space and time instead. Now imagine our universe frozen in a static state, at a moment in time, who could "read" it? Not us, as we would be frozen too! A frozen world without an observer would be like this page without a reader – *dead*. And if the physical universe is all there is, where could an observer of it exist? What Einstein deduced for light also applies to existence. If our world could exist in a static state, i.e. frozen, it would have no information per se. It follows that we need to change our ideas of what existence is.

The network in this model has no static memory of any sort, i.e. no caches, or buffers. All our devices, from servers to cell-phones, have storage but a *dynamic processing system* doesn't. Static information needs an encoding context, but a processing act has no context other than the options offered, in a *choice* where all options are possible at once, as in quantum superposition. If dynamic quantum processing generates static physical states, the trans-humanist dream of mind uploading isn't possible, as even a perfect brain "image" would be no better than a photo of a movie, which isn't a copy. And by the *quantum no-cloning theorem*, quantum processing can't be downloaded, saved or uploaded. Quantum reality consists of dynamic *events* not static *things*, so the only way to "store" an event is to repeat it. In Chapter 4, static matter arises in this way.

2.2.2. 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.
2. OR 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 physics equations, such as the classical problem that light has no mass so it should go infinitely fast[4]. Relativity resolves this by giving a photon relativistic mass, an invention that explains what is. The infinities of quantum field theory were likewise resolved by the mathematical trick of "renormalization", of which Dirac wrote:

"*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!*"

And Feynman said the same even more bluntly:

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

We sometimes forget that continuity is a mathematical convenience, not an 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 that space and time are continuous, rather than discrete...*" (Barrow, 2007) p57

A digital world of irreducible pixels and indivisible ticks makes the infinities of field theory disappear like ghosts in the day, as denying the infinitely small avoids the infinitely large. Computing has no "half pixels" or

[4] In classical physics, $F = m.a$ where F is force, m is mass and $\underline{a}$ is acceleration, so if $a=F/m$, a force acting on a zero mass photon should give infinite acceleration.

"half cycles" so a virtual reality can't be continuous. Processing as a choice from a finite set can't give infinite values. A virtual world is finite because repeatedly dividing a digital space gives a pixel that can't be split and repeatedly dividing a digital time gives a cycle that can't be paused.

In our world, continuity breaks down at the order of Planck length and time. To study these limits needs short wavelength light, which is high energy light, but putting too much energy into a space gives a black hole that screens information from us. If you probe the black hole with more energy, it just expands its horizon to reveal no more, so what occurs below the Planck length is unknown. Just as inspecting a TV screen reveals only dots and refresh cycles, so inspecting our physical world closely reveals only Planck limits. If our world is an image on a screen, physicists know its resolution and refresh rate[5].

2.3. SPACE CALCULATES

2.3.1. Is space nothing?

The question of whether or not space itself exists has concerned the greatest minds of physics. Simply put:

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

Newton saw space as the canvas upon which objects are painted, that still exists even without the objects. To Leibniz, a substance without properties was unthinkable so he saw space as a deduction based on object relations. If objects only "moved" with respect to each other, without matter there would be no space. An empty space has no "where" to put things, and distance is just the length between two marks on a platinum-iridium bar in Paris. So is space something or nothing?

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 are spinning 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 their arms splay out by the spin. One *could* see this as relative movement, as the stadium spinning round the skater, but then the skater's arms wouldn't splay. So the skater *really is spinning* in space (Greene, 2004) p32.

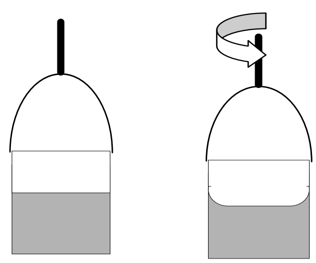

Figure 2.2 Newton's' bucket.

This seemed to settle the matter, until Einstein showed that objects really do only move *relative* to each other. Mach then tried to resurrect 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 is untestable as we can't empty the universe. This willingness to invoke zombie theories 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

In contrast, a simulation could handle object interactions two ways:

1. *By absolute coordinates.* In this centralize solution, each photon or electron has a recorded position that changes each cycle. Every cycle the positions are compared to see if a collision has occurred. The inhabitants of this virtual reality would see a space that is truly nothing, but for a simulation the size of our universe, to compare every quantum state every quantum cycle would be an unthinkable processing task.
2. *By local overloads.* In this distributed solution, each point of space is a node that processes any program passed to it. Collisions aren't central calculations but local overloads that occur if a node gets more

[5] Planck length of 10^{-33} meter is the pixel resolution. Planck time gives 10^{43} times per second as the refresh rate.

processing than it can handle. These inhabitants see a space that is discontinuous and exists apart from the objects in it.

In reverse engineering, the less processing is preferred, and it is also the current verdict of physics that:

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

Yet space as a processing network is no more the passive canvas of Newton than it is the nothing of Leibniz, because *null processing* is doing something even when it is doing "nothing".

2.3.2. Euclidian space

That space is a "something" raises the question *What does it do?* It seems strange to talk of what space "does", but computer 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, Jurkiewicz, & Loll, 2008) p25.

Euclid defined the structure of space many years ago. He began with a *point* that extended continuously as a *line* that extended at right angles became a *plane* that extended again was a *cube.* So space is a set of cube volumes in three *dimensions* that define every point within it. That war-gamers divide their maps into hexagons not squares to give more *directions*, suggests that a space like ours requires:

1. *Locations*. Objects exist at locations so two objects "in the same place" collide, i.e. interact.
2. *Dimensions*. There are three dimensions of movement.
3. *Directions.* We move in apparent straight line directions (geodesics).

A Euclidean space can represent any point by Cartesian coordinates, (x,y,z), i.e. three real numbers.

2.3.3. Scalability

Simulating space as a network isn't a new idea. In Wilson's networks each node is a volume of space, and in Penrose's *spin networks* each node is an event with two inputs and an output (Penrose, 1972). However models that map nodes to Cartesian points, like loop quantum gravity (Smolin, 2001), cellular automata (Wolfram, 2002) and lattice simulations (Case, Rajan, & Shende, 2001) encounter the problem of *scalability*.

Berners-Lee defined a *scalable* system as one that doesn't lose performance as it grows, however big it gets (Berners-Lee, 2000). He designed the World Wide Web to this principle, that growth should increase demand and supply in tandem. If every new ISP[6] demand also increase the processing to handle it, the system can grow forever. To implement such a system, it had to be distributed, but when the idea of a decentralized Internet was first mooted, pundits predicted that it would collapse into chaos due to lack of control. Yet it didn't.

It was later discovered that an infinity anywhere in a centralized system can crash it, but distributed systems that *localize control* can carry on. Our brain as a biological processor evolved this way, so it *shares control* between cortical hemispheres instead of having a central processing unit (CPU) (Whitworth, 2008). The bottom line is that Cartesian coordinates work for small spaces but aren't *scalable,* because they require:

1. *A pre-known size:* A maximum size to define the coordinate memory allocation[7].
2. *A zero point origin*: An absolute origin, i.e. a central (0,0,0) point.

[6] The nodes of the Internet network are Internet Service providers, or ISPs.

[7] A point in a 9 unit cube is stored as (2,9,8) but in a 999 unit cube is stored as (002,009,008), i.e. more memory.

The bigger such a system is, the more memory is needed to store its coordinates. So our universe as a Cartesian space would need a maximum size defined *before the first event* to avoid a Y2K problem[8]. Yet it is still growing to an as yet undefined size, and the evidence is that it has no absolute center.

The performance of our space hasn't changed much after expanding for billions of years, so like the Internet it must be scalable. If the expansion of space adds more nodes, it adds more locations and more processing to handle them, i.e. it is scalable. That this requires a distributed network implies local limits:

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

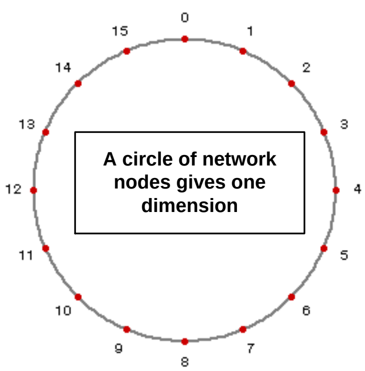

Figure 2.3. A circle surface is 1D

Black holes then expand as matter falls into them because a black hole is the processing limit of space, i.e. its "bandwidth".

2.3.4. A rotational architecture

Euclidian space is so deeply ingrained in western thought that we often think it is the only way a space can be, but one can use *polar coordinates*[9] based on rotations rather than straight lines. They are mathematically the same but instead of beginning with a point that makes a line, one begins with a point that creates a circle. In network terms, a circle is one-dimension as every node has two neighbors, giving left and right directions (Figure 2.2) where a node linked directly to another is "near" but one many links away is "far". Just as we measure Web distances in mouse clicks not screen inches, so in a network "distance" and "direction" derive from its *architecture*, i.e. how the nodes connect.

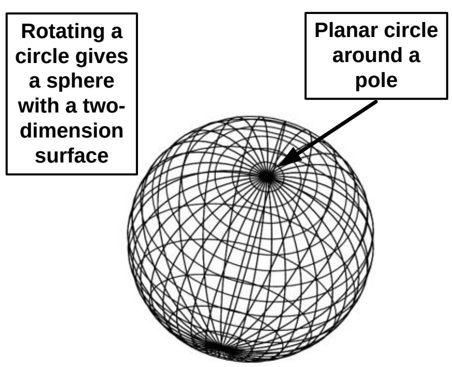

Figure 2.4. A sphere surface is 2D

If the circle in Figure 2.3 is one dimension, it can be rotated again to give a two dimensional sphere surface (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 is the center of the sphere surface.
4. *Approximately flat.* If the sphere is large enough.
5. *Simply connected.* Any loop on it can shrink to a point.

This surface is like our space except it only has two dimensions, but another rotation can give a three dimensional surface. If one rotation is a circle whose surface has one dimension, and two rotations is a sphere with a surface of two dimensions, three rotations is a *hyper-sphere* whose surface has three dimensions (Figure 2.5). A hyper-sphere is what you get when you rotate a sphere, just as a sphere is what you get when you rotate a circle. It is well defined mathematically, but while a sphere surface has only two dimensions, a hyper-sphere surface has three. The mathematician Riemann centuries ago speculated that our space was a hyper-sphere *surface*. His logic was that the facts fit: a hyper-sphere surface is unbounded, simply connected and three-dimensional just as our space is. The logic today is even more impressive, as space is said to grow everywhere at once with no center or edge, just as an expanding hyper-sphere surface would. Mathematically, our three dimensional space could be the surface of a four dimensional bulk:

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[8] Before 2000 older computers stored years as two digits to save memory, e.g. 1949 was stored as "49". The "Y2K" problem was that the year after 1999 was "00", which was used for 1900. A lot of money was spent fixing this problem.

[9] 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.

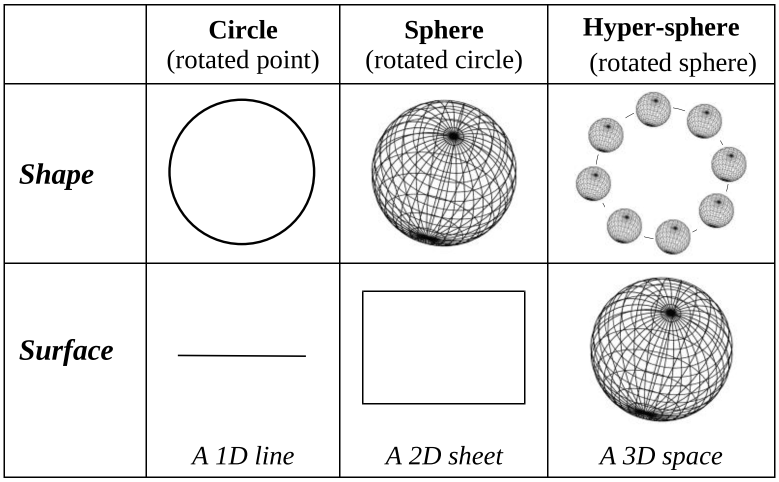

Figure 2.5. A hyper-sphere surface has three dimensions

"*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

Yet a polar coordinate system has an absolute center so it is no more scalable than a Cartesian one is.

2.3.5. A relative space

No system with an absolute zero center is scalable nor can it emulate special relativity, where every point of space has its own coordinates of space and time, e.g. one observer can see event A occur before B, and another can see B occur before A, i.e. two observers can sequence *the same events* differently. This is only possible if space and time are *locally defined*.

In Figure 2.3, the "pole" node chosen is arbitrary. Any node on the sphere surface could be a pole depending on the rotation axes used to create the sphere. A sphere surface has as many different sets of polar coordinates as there are axis poles, but each set maps the same surface, and in network terms this just changes how the nodes connect. Now for a fully connected network to alter its node links is easy, e.g. cell phone networks routinely change their connections to improve efficiency. So let each node *locally configure itself as a pole* by setting its own connections so. It then "paints" its own coordinates, or as relativity says, has its own frame of reference. This does not allow an objective view, but a system that is only ever seen from within has no need for that.

A relative space requires a network that distributes control, letting every node choose its neighbors as if it were the center of all space. So each node has a different view but every view is equivalent. If a *network* allocates nodes to points on demand, as the Internet allocates IP addresses, it can support a relativistic space.

2.3.6. The granularity of space

The *granularity* of a network simulated space depends on the number of steps in each rotation that creates it. A perfect circle has infinite steps, but a *discrete circle* has a finite number, where a triangle can be seen as 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, so it might seem that more steps is better to give more directions, but war-gamers avoid octagons since they don't fill the board. More granularity gives more spatial directions, but a large N-circle can't fill a Euclidian space.

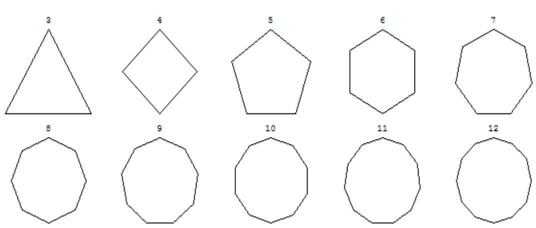

Figure 2.6. Discrete rotations, N = 3-12

This means that not all paths in this space are reversible, i.e. retracing a route taken may not return to the exact same node, though it will be a true vicinity. In essence, a discrete space based on polar coordinates will have "holes" in it, so the standard model's point particles could pass right through each other! Fortunately in quantum realism, as in quantum theory, entities exist as quantum clouds that "collide" as they overlap over an area, so a space with a few holes in it is ok. *That quantum entities exist inexactly avoids the problems of an incomplete discrete space.*

The granularity of the grid network predicts a finite number of directions for any quantum event. If direction, like length, is quantized, there will be a minimum *Planck angle*[10].

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

2.3.7. Space as a hyper-surface

In 1919, Kaluza derived Maxwell's equations by expressing Einstein's relativity equations in four dimensions, but his peers saw his extra dimension as a real one. If there was a fourth dimension, gravity would vary as an inverse cube and the solar system would collapse, so they dismissed his idea. Yet mathematics already had *complex numbers* that explained electro-magnetism as a rotation into a fourth dimension, but it was "imaginary" so physical realism wasn't contradicted.

Klein then suggested that perhaps Kaluza's dimension was *compactified*, curled up in a tiny circle so entering it returned you to the start, but he also was ignored - until years later string theorists needed to explain their six extra dimensions. Today, they maintain that space contains their extra dimensions *within it*, but why would Nature have extra dimensions that do nothing except make our equations work?

In this model, every virtual reality presents on a screen, so an extra dimension is needed to contain that surface. If space is our screen, its three *transfer dimensions* must be contained by another, but unlike string theory, it *wraps around* our reality rather than *curls up* within it, i.e. it is too large for us see not too small.

Today, physicists like Randall and Sundrum use the idea of extra dimension *sequestered* from our space to explain gravity (Randall & Sundrum, 1999), where our space is a *brane* in a higher-dimensional *bulk*:

> "*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

2.3.8. Quantum waves

All waves vibrate up and down on a surface, so if a pool top is sealed in concrete no waves can travel on it, as the water molecules can't move up and down. Every wave needs a dimension orthogonal to its movement direction to vibrate into. It is then "sequestered" from that dimension because it cannot leave the surface it vibrates upon.

In quantum realism, quantum waves move on the surface of space. 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, horizontally, but the water just moves up and down, transversely. This is why a cork just bobs up and down as a wave passes. What moves horizontally as a wave is a set of *transverse changes*, i.e. dynamic information.

A photon as a transverse wave on the surface of a space can't move in its vibration direction, so if matter arises from light (Chapter 4) neither can we. We can no more leave our space to enter the "imaginary" quantum dimension than an onscreen avatar can leave a computer screen.

A photon wave arises from displacements just as a water wave does, but the positive and negative values of electro-magnetism are not physical changes. In current physics, electro-magnetism is a *rotation* into an "unreal" complex plane. In quantum realism, it is a rotation into a real quantum dimension. This rotation transverse to space is the basic processing unit of this model: a *Planck program* that sets a circle of values transverse to space. As a processing task, a circle of values is easy to run since its end leads to another beginning. As a fundamental network command, it either runs or it doesn't. Yet like Monopoly money, the values set have no intrinsic meaning apart from the virtual reality. In one node, this program's equal and opposite displacements cancel out, so we call it empty space, and in the next chapter this program spread over many nodes is light (Figure 2.7).

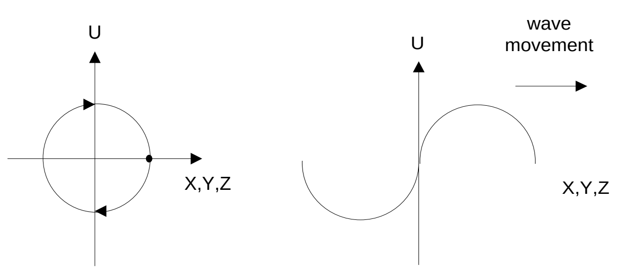

Figure 2.7. A Planck program as a. Space and b. Light

The idea of a rotation into a dimension we cannot see seems strange, but unreal complex numbers that do just that are basic to quantum theory. Schrödinger's equation describes an electron as a three-dimensional wave whose value at any point the mathematics *defines as unreal*. 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 the entity exists there, but a probability is just a number. One might expect the ultimate formula of our reality to be something physical, but it isn't. As far as we can tell, the quantum amplitude that defines the physical world isn't based on mass, momentum, velocity or any other physical property. If quantum processing creates physical matter, then the *substantial arises from the insubstantial*.

2.3.9. The transfer problem

In our world, freely moving entities travel in a straight line, which is the shortest distance between two points. The general term is *geodesic*, as on a curved surface like the earth a longitude is the shortest distance between two poles. Space defines the lines that things naturally move along, so to Einstein gravity acts by "curving space", i.e. changing the geodesics.

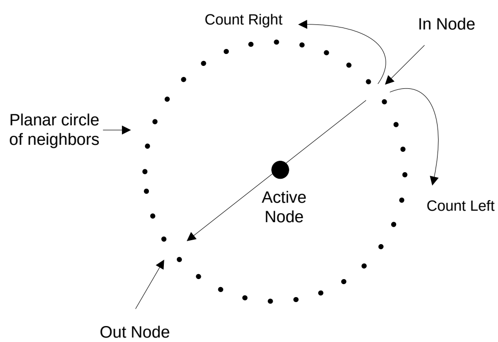

Figure 2.8. Planar circle transfers

Suppose that:

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

In a quantum network, a point is a node and a photon is a Planck program transmitted by it. The directions of space arise as each node links to neighbors by transfer channels. How nodes receive and pass on programs defines the geodesics. A network must define how processing packets pass between nodes, and the transfer problem is the question of how to do this.

Every photon has a polarization plane that affects the filters that block it. In this model, that plane is transverse to its oscillation *on* space. If every node acts like *pole*, it defines longitudes radiating from it that define its transfer directions. So let a *planar circle* of neighbors in its polarization plane manage the photon transfer, just as in quantum Hall models two-dimensional *anyon* excitations simulate space transfers more simply (Collins, 2006). This reduces the transfer problem to finding the "Out" node for any "In" node in a planar circle. A simple rule is to count both ways from the entry node until an overlap defines the exit node. If the input from any node in a planar circle is output to the *opposite* node (Figure 2.8), the transfers will be the least for any route, i.e. a straight line. A network that maximizes the separation of entry and exit nodes in planar circle transfers will minimize the number of transfers for any route, i.e. create geodesics.

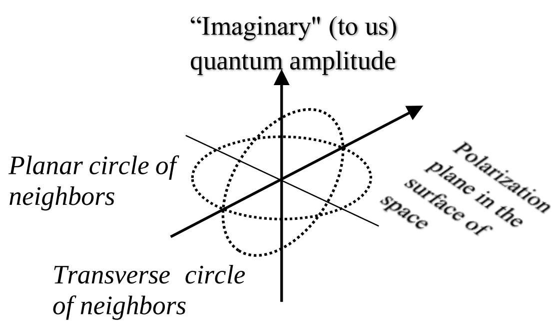

Figure 2.9. Planar and transverse circles

2.3.10. Recap

A grid network connected in four dimensions can contain our space as a three-dimensional surface. This seems complicated, and in practice it is, but for *one node* running *one photon*, the only neighbors that count are the *transverse circle* that defines its quantum amplitude and the *planar circle* that defines its transfer directions (Figure 2.9). A transfer rule that maximally separates planar circle entry/exit nodes can represent the geodesics of space. In Chapter 5, the load differential of gravity bends light by skewing this transfer.

2.4. TIME AS PROCESSING

Does four dimensions of space-time plus another processing dimension mean five dimensions in all? Quantum realism has only four dimensions because our time arises from cycles in the processing dimension.

2.4.1. Virtual Time

Objective time should pass inevitably, by its own nature, needing nothing else, but virtual time depends on processing cycles. For example, in Conway's Life simulation (Figure 2.10), pixels reproduce and die by program rules. Blobs are born, grow and die in a simulation whose time passes as processing events occur. A blob that has many events lives (for it) a long time, while a few events are a short time. We measure time the same way in our world, as atomic clocks just count atomic events. If a Life game where a blob lives for twenty minutes is run again on a faster computer, it might only run for a few seconds, but *to it*, its virtual life was the same as the same number of events occurred, i.e. virtual time depends only on *the number of processing cycles that occur*.

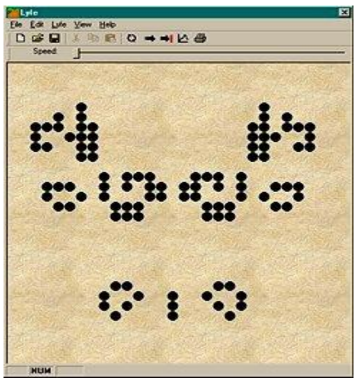

Figure 2.10. Conway's Life

If a computer game slows down under load, say in a big battle, the observing player sees the screen lag, but for an onscreen avatar nothing would change, as *they also slow down*. So if our time is virtual, we wouldn't know if it slowed down, and indeed relative changes in space-time are undetectable to the parties affected. The effect is only revealed when people under different *local loads* later compare times, e.g. in Einstein's twin paradox, a twin travels the universe in a rocket at near the speed of light and returns a year later to find his brother an old man of eighty. Neither twin knew their time ran differently and both still got their allocated number of life breaths, but one twin's life is nearly done and the other's is just beginning.

In this model, the processing cycles of matter are time passing for it. So if a photon moves on every cycle, no time should pass for it, and indeed according to Einstein, for light, no time passes. Equally if the grid is busier in one place than another, the cycles completed, i.e. the time should vary, and again it is so. In the twin paradox, the rocket twin was moving so fast that the grid was only able to process a year's worth of events for him, so he only aged a year, but the twin on earth had no such load, and eighty years of his life cycled by in the usual way. Only when the two re-united was it apparent that their virtual times had run at different rates. This is not just theory, as in particle accelerators short lived particles live many times longer than they usually do.

2.4.2. Specifying time

A system to simulate a time like ours would have to support:

1. *Sequence*. The passing of time requires a sequence of events.
2. *Causality*. Time allows one event to cause another.
3. *Unpredictability*. In time, the future is unpredictable.
4. *Irreversibility*. Time cannot go backwards[11].

A virtual time that acts like ours must be sequential, causal, unpredictable and irreversible, and processing cycles can satisfy these requirements, as follows.

Sequence

An objective time could derive from a sequence of pre-existing states, as a movie is a sequence of pre-existing pictures. Such a "time capsule" of states could be browsed like a book (Barbour, 1999) p31, but if past, present and future states already exist, in a "timeless time", then *life is a movie already made*. That our time derives from a set of static states in a big database has two problems:

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[11] The special case of anti-matter is considered in Chapter 4.

a) *Unbelievability*. The universe's quantum states at any moment are innumerable and its cycle rate unimaginable, so the storage needed is unbelievable.
b) *Irrelevance*. Why store in a database *quantum events* that mostly don't occur? Why even store all physical events, as who would want to read a "history" World War II as atomic events? Or if only what is important is put on the record, how is that done[12]?

If time passes in discrete processing cycles, things do change in infinitesimal amounts! Zeno concluded correctly that a sequence of static physical states can't create movement, but the dynamic events behind them can. We can replace time in our equations with a delta time because processing cycles create physical reality[13].

Dynamic processing has no static storage but perhaps the physical world *is* its storage. If one physical state arises from countless quantum states, the physical world *is* the selection of what is important from the quantum world. The lawful generation of a series of static states is in essence a database report. We query reality to get the status update we call the physical world. This ongoing report can contain not only the present but also the past. Indeed our only record of the past is the present, whether as neural memories that exist *now* or as dinosaur fossils that exist *today*. Our DNA is a repository not just of our ancestors, but of all life on earth. In this system, *genes* (Dawkins, 1989), *memes* (Heylighen, Francis & Chielens, K., 2009) and *norms* (Whitworth & deMoor, 2003) survive by their generative power, but that which lives for itself alone passes away. The physical world is then the quantum world's solution to its storage problem, and the ongoing choices of the universe decide what is stored.

Causality

In this view, time is a processing byproduct not an absolute context, as each event outputs the input to the next, so quantum states:

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

Causality then arises not from static states but from dynamic events:

"*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

Processing implies a sequence of state outputs, but to see them as the cause of everything is to see reality backwards. If each set of processing events define the next, no intervening physical "things" are necessary. Causality still arises if what current theory calls an evolution of states is an evolution of events.

Unpredictability

Any choice that creates information has by definition a "before" and "after": before there are many options but after there is only one. If the choice set defines the option chosen, it isn't by definition a choice, and no information arises. So if the physical world is virtual, the quantum collapse behind every physical event must be a free choice, and indeed it is. Hence even knowing every physically knowable thing, we can't predict when a radio-active atom will emit a photon. Querying an electron causes its quantum wave to instantly *choose* a point in space-time to "be" an electron with some spin. As *every* physical event involves a quantum collapse, *all* physicality is unpredictable. So if the quantum world is a machine, it is one with:

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

We are surprised when physical events like radiation are *random*, in a way that no prior physical "story" can explain, but according to quantum theory, *every* physical event is random. Choice, and the randomness it implies, are as fundamental to this model as particles are to the standard model. The wave function mechanically evolves the quantum options, but choosing one to be a physical event is a server act unpredictable in our world.

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

[13] For any calculus involving time, replace *dt by ds*, the state *difference*. Now *ds*, the number of intervening cycles, can indeed "tend to zero", when one cycle gives the next with none in-between.

Irreversibility

As the laws of physics are time reversible, physicists wonder why time can't run backwards? What creates the arrow of time? Time as a sequence of static states could reverse, as could a sequence of processing events, so why does time always go forward? The following paradoxes show why it must be so in our world:

a. *The grandfather paradox:* A man travels back in time to kill his grandfather, so he could not be borne, so he could not kill him. One can have causality or travel back in time, but not both.

b. *The marmite paradox* I see forward in time that I will have marmite on toast for breakfast, but then choose not to, I so didn't rightly see forward in time. One can have choice or predictability but not both.

In quantum realism, a physical event is irreversible because it is a processing reboot. In our computing, a reboot is a processor reloading its programs from scratch, e.g. turning a computer on and off reboots it, and loses any work you were doing, unless you saved it! One can't *undo* a reboot because a processor that restarts loses whatever it was doing before. When the processor stops to reboot, whatever it is currently doing is gone forever. In this model, a physical event as a node reboot is irreversible. A virtual time may slow down if the processing load increases, but a physical event as a quantum reboot implies the arrow of time.

2.4.3. Recap

A virtual time created by processing punctuated by an occasional reboot can be sequential, unpredictable, causal and irreversible, just like ours. Space and time are convenient ideas for ordinary life but they don't explain the extraordinary world of physics. When we first hear Einstein's view that time and space are malleable, we suspect a trick, but it is no trick. It is not *perceived* time or space that change but *actual* time and space, as measured by instruments. This is only possible if our space and time are virtual.

We see time as a stream carrying all before it and space as a canvas upon which all exists, but a little thought denies this. How can a space that defines all directions itself "curve", as Einstein says? How can a time that defines all change, itself change[14]? A time and space that change can't be fundamental:

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

In quantum realism, our space arises from the grid connection architecture and our time arises from the processing cycles of its nodes. In this "*Physics of Now"* (Hartle, 2005) p101 there is no past or future, no back and forth time travel, only *an ever-present here and eternal now.*

2.5. IMPLICATIONS

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

2.5.1. The big bang?

In 1929 the astronomer Hubble found that all the galaxies were expanding away from us, implying a "big bang" in space-time about 14.5 billion years ago. Finding cosmic background radiation all around us, as static on our TV screens, confirmed that not only did our universe begin, but that its space and time did too. Ignoring that a *complete universe can't create itself*, how can a space that defines the term "expand", itself expand? A first event means the universe began at some point in space, so if everything is moving away from us, are we that point? And if the universe is expanding, what is it expanding into? How can a "big bang" explode space as well as itself? And if everything exploded "out", why is the first light still all around us today, as cosmic background radiation? To such questions physicists reply that *we don't understand*, that the big bang wasn't really a bang, that space is expanding everywhere at once and that this expansion has no edge, but just restating in English what the equation already says symbolically imply doesn't explain *why* it is so. And if it wasn't really a bang, why call it one?

---

[14] That time changes gives *dt/dt*, which must be a constant, so that time itself changes is impossible.

In physical realism, *in the beginning* the universe began from nothing, then became a singularity of all the stars and galaxies at one point, although that much energy at a point should form a black hole from which nothing can emerge. In the so called big crunch, our universe collapses back into a black hole, so why didn't the initial singularity do the same? Then according to inflation theory (Guth, 1998) an immense anti-gravity field came from nowhere to expand the universe faster than the light for 10^{-32} seconds, then it just vanished to play no further part in the universe. Today's creation myth is that everything came from nothing into a singularity that inflated faster than light for no reason then stopped for no reason, giving the galaxies, stars and us. It isn't a very convincing story.

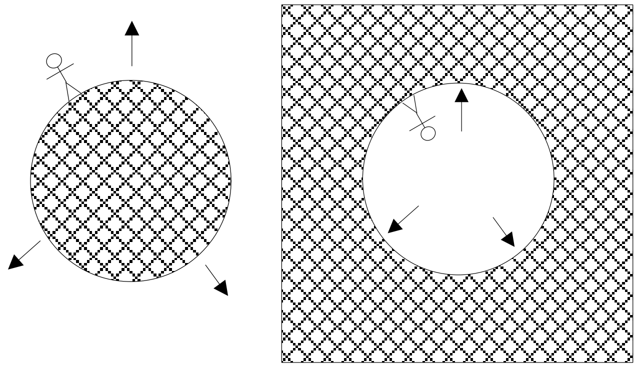

Figure 2.11: a. A big bang in pre-existing space, b. A small rip in a bigger bulk

In quantum realism, *in the beginning* was a quantum quintessence we don't understand, here envisaged as a processing network called the grid. It emulates our space as the *inner surface* of an expanding hypersphere that has no center or edge, just as a sphere surface has no center or edge. Like a balloon with dots on it being blown up, our space is expanding everywhere at once. Electro-magnetic waves that move on that surface travelling in any direction will go around it, so the first light went "out" then wrapped around to end up everywhere, as cosmic back-ground radiation is today. That space is the *inner surface* of an expanding four dimensional bubble (Figure 2.11) answers questions like:

1. *What is space expanding into?* It is expanding into the surrounding four dimensional *bulk*.
2. *Where is space expanding?* Everywhere, as the bulk fills "gaps" that arise everywhere.
3. *Where does the new space come from?* From the surrounding bulk that contains the bubble.
4. *Are we expanding too?* No, existing matter isn't affected as new space is added.
5. *Did the universe begin at a point singularity?* No. It began as one photon only (see next section).

2.5.2. The small rip

This model sees the first event in *client-server* terms, where a *server* services many *clients* as they request, e.g. for terminals on a network, each keystroke is a request to a server that responds much faster than its clients. Even for a person typing as fast as they can, in-between each key-stroke a server can deal with hundreds of other people typing at the same time. So if a photon is a server program passed between grid client nodes, the server-client connection is much faster than the node processing cycle.

Before the first event, the grid existed as a network connected in four dimensions. Then for some reason, one node disconnected itself from the grid by passing it's processing to its neighbors, and acting as a program server. This created within the grid the *surface* we call space, and the vibration moving upon it that we call light. The first event created both the *first photon* and the *first space* simultaneously, and as it all began with just one photon, no singularity or black hole occurred.

Inflation was the cataclysm that followed, as the first photon "broke" other nodes too. Imagine an incredibly taught fabric where a pin-prick hole quickly becomes a huge rip. As each photon created others, the "rip" *chain reaction* spread at the *server rate*, i.e. faster than the *node cycle rate* we call the speed of light. Inflation created all the free processing of our universe from the body of the original bulk, in a once only chain reaction that will not repeat (Davies, 1979). Galaxies formed as the universe cooled, but never again will the grid itself "break", so the net processing of our universe is, and since inflation has been, constant.

Why did inflation stop? Each photon creation also created a point of space that inserted into the wavelength of a photon diluted its power. If the photon creation chain reaction grew at an exponential rate, space as a hypersphere surface increased as a cubic function, and a cubic growth will overpower an exponential one if the resolution is quick (Figure 2.12), and by some estimates inflation was over in less than a millionth of a second. The expansion of space healed the grid injury to stop inflation, but space continued to expand, and so cosmic background radiation that was white hot at the dawn of time, is now cold.

In quantum realism, the separation of nodes as servers broke the original symmetry. Three of the grid's four dimensions became space and the other existence in time, as in the Hartle-Hawkin theory, that at the first event *one of four equivalent dimensions became time and the rest became space* (Hawking & Hartle, 1983).

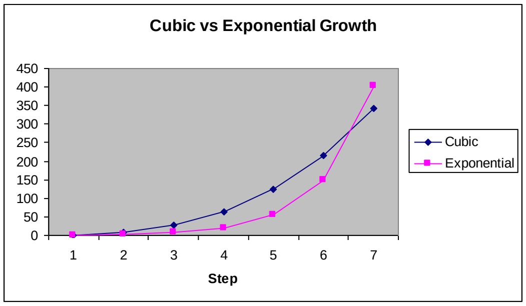

Figure 2.12. Cubic vs. exponential growth.

In quantum realism, the physical universe came from something not nothing, the "big bang" wasn't big (at first anyway), it wasn't a bang but a rip, there never was a singularity and the first event as the creation of one photon in one volume of space explains both why inflation started and why it stopped. If the expansion of space both stopped inflation and caused the first light to descend into the lower and lower frequencies necessary for life, it isn't just an oddity of physics. It is why we are here at all.

2.5.3. The synchrony problem

A network must synchronize its transfers, as if two transfers arrive at a node that can only run one, one will "disappear". In a virtual reality, information sent but not received doesn't exist. We solve this problem by:

1. *Centralization*. A central processing unit (CPU) synchronizes all transfers to a common clock.

2. *Buffers*. Each node has a memory buffer to store any overloads, as the Internet does.

These methods won't work for a simulation of our world, as is now explained.

Centralization

If a central processing unit (CPU) issues a command to move data from memory into a register, how does it know *when* it happens? It cycles faster than the data transfer rate, so it must wait for it to happen, but how many cycles? If it reads the register too soon it gets past garbage, but if it waits too long it wastes action cycles. Can it look to see if the data arrived? Issuing another command needs another result register that also needs checking!

We solve this problem using a central clock, like a conductor keeping time for an orchestra. The *clock rate* of a computer is the number of cycles it waits for any task to be done. The central CPU server issues a command, waits for a clock rate of cycles, then reads the register. If one "over-clocks" a computer, by reducing its clock rate from the manufacturer default, it initially runs faster, until at some point this gives fatal errors. If the universe had a clock rate, it would have to run at the speed of its slowest node, e.g. a black hole where time stops.

Buffers

Network protocols like Ethernet[15] improve efficiency tenfold by letting each node run at its own rate, with buffers handling any excess. If a node is busy when another transmits, the buffer stores the data until it is free. Buffers let fast devices work with slow ones, e.g. if a computer (fast device) sends a document to a printer (slow device), it goes to a *printer buffer*, so you can still use the computer while the document prints.

---

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

Too big buffers waste memory but too small buffers overflow and slow down the network, as transfers must repeat. Buffers work best if their size fits their location, e.g. the Internet allocates big buffers to backbone servers like New York not backwaters like New Zealand. Yet where galaxies with black hole centers arose in our space wasn't initially known. A simulation that buffered every point in the vastness of space would be wasteful. Yet a network without buffers allows *transfer deadlock,* where A waits for B that waits for C that is waiting for A (Figure 2.13). If our universe was like this, a part of space could like a dead screen pixel, be unusable forever.

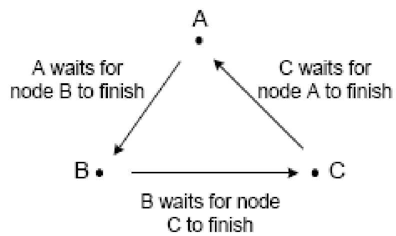

Figure 2.13. Transfer deadlock

The conservation of processing

If a SimCity program loses information, an object in it could suddenly disappear as if it never existed. Imagine if our world did that! If the processing of a virtual reality "leaks" entities will be lost. Our universe has run for billions of years, with no evidence that even one photon has been lost, so what ensures this? In this model, a physical event is processing re-allocated by a grid node reboot, so the processing before and after every interaction *must* be the same. To the traditional conservations of matter, charge, energy and momentum, quantum theory adds spin, isospin, quark flavor and color, but each "law" is partial, e.g. matter is not conserved in nuclear reactions and quark flavor is not conserved in weak interactions. In quantum realism, all these conservations are replaced by a law of *conservation of processing*: that in any physical interaction, the net processing is always conserved[16].

2.5.4. The pass-it-on protocol

Centralization is inefficient and buffers are unreliable, but neither option is available to a dynamic distributed network, so how can it maintain synchrony? If node transfers waited for destination nodes to finish their cycle, the speed of light would vary for equivalent routes, which it doesn't. That light doesn't wait implies a *pass-it-on protocol:* that nodes immediately receive any input as an *interrupt*. Won't this lose data? Not if every node passes it's processing to its neighbors, *then* processes what it receives. This could create an infinite regress, except that space is expanding, i.e. adding new nodes. Any pass-it-forward ripple will stop if it meets a new node that accepts the extra processing without passing anything on. In this protocol, nothing ever waits, so there is no need for static buffers. Light always moves on one node every sender cycle, every packet passed on is accepted, and the expansion of space nullifies infinite pass-it-on loops.

2.5.5. Empty space is full

If empty space was really empty it would be empty of energy, but in quantum theory:

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

In this model, empty space is null processing, like an idle computer that is actively running a *null cycle* over and over. So *empty space isn't empty* (Cole, 2001), as illustrated by:

a. *The Casimir effect.* Two uncharged flat plates nearby in a vacuum feel a force pushing them in. Currently, this *vacuum pressure* is attributed to virtual particles pushing the plates in, but how can an emptiness create things? In this model, the closeness of the plates interferes with the grid oscillations between them but not around them, causing the pressure with no virtual particles needed.

b. *Vacuum energy*. What physics calls the *energy of the vacuum* arises because in quantum theory a point can't have no energy. A space of truly nothing wouldn't have this property, but null processing does. It can average zero, as a cycle of positive and negative values does, but it can't be constantly null.

c. *The medium of light.* How can light vibrate space, i.e. nothing? A space that mediates light can't be nothing. As a screen, it can be both blank (nothing) and mediate an image (something).

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[16] Except for the initial event, but see 2.5.1.

That empty space is a physical "something" implies a reference frame to movement that the Michelson–Morley data denies, but Einstein concluded that without some sort of ether, relativity was unthinkable:

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

Quantum theory also 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.

In this model, a space that seems empty to us is actually *full* of processing. This "fullness" is the grid network that mediates light, generates vacuum energy and produces the Casimir effect. So there isn't a physical ether but there is a non-physical grid that mediates all physical events.

Imagine a large window with a view. One sees the view but not the glass transmitting light carrying it. One only sees the glass if it has imperfections, if there is a frame around it or if one touches it, but the "glass" of space:

a. Transmits with no imperfections, so it can't be seen directly.

b. Is all around us, so has no surrounding frame to detect it by.

c. Transmits matter as well as light, so we can't touch it.

Like a network of *perfect diamonds,* the quantum grid flawlessly reflects light and matter within itself.

2.6. THE EQUATIONS ARE TRUE

A century ago, physics left the haven of classical mechanics for the promised lands of relativity and quantum theory. It discovered quantum waves, higher dimensions, time dilation, curved space and other wonders, but now sits in the desert of physical realism, beneath the mountains of physical reality, convinced that beyond them *there is nothing at all.* Yet *The Trouble with Physics* (Smolin, 2006b) is that no theories grow in this place, so what puzzled Feynman fifty years ago still puzzles us today. Experts write notional papers about strings, multi-verses, supersymmetry and WIMPs to rally the troops, but they are *Not Even Wrong* (Woit, 2007) - not even the weeds of error grow here. The crisis is that without new ideas, the next fifty years of physics will be like the last – theoretically barren.

Quantum realism offers the alternative that there actually is something beyond the physical world. It is not a heaven or hell but a quantum world that quantum theory has already mapped and quantum computing is already using. We can't see it, but we can reverse engineer the processing that underlies it, and test our theories with a simulation. This approach doesn't change the equations except to promote them from imaginary friends to real ones. In quantum realism, *the equations we use are literally true*:

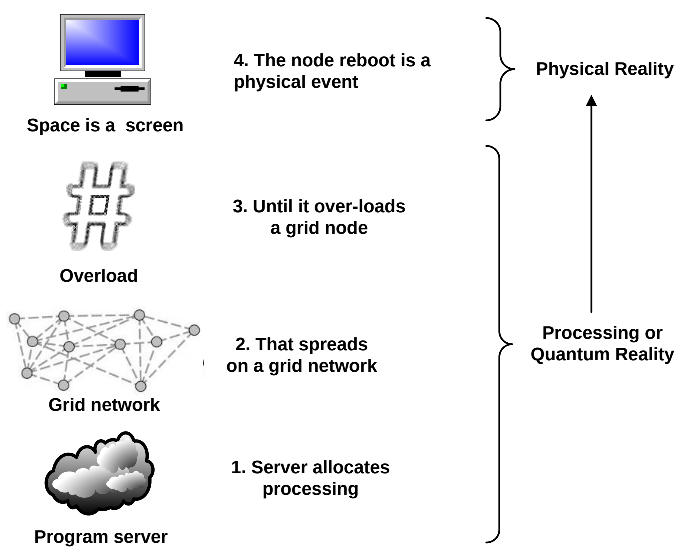

Figure 2.14. Processing produces physical reality

1. *Quantum randomness* is independent of physical history because it is server generated.

2. *Complex numbers* work because light really does rotate into another dimension.

3. *Kaluza's dimension* unites relativity and Maxwell's theory because it really exists.

4. *Planck limits* exist because space and time really are digital.

5. *Calculus* works because infinitesimals, in the limit, really do create physical reality.

6. *Feynman's sum over histories* works because quantum entities really do take every path.
7. *Special relativity* lets our time dilate because it arises from processing cycles.
8. *General relativity* lets our space curve because it is indeed a "screen".
9. *Cosmic background radiation* is still all around us because a hyper-sphere surface has no center or edge.

If the equations of quantum and relativity theory are good enough to use, they should be good enough to believe! Figure 2.14 summarizes the model so far, where quantum entities, like a photon, are programs running on a client-server network. This chapter argued that *space* is a null Planck program running in one node. In the next chapter *light* is the same program spread over many nodes, and in Chapter 4 *matter* is light infinitely rebooting in

Table 1. Space and time as explained by physical realism and quantum realism

Physical Realism	**Quantum Realism**
Flux. The physical world is constantly in flux for some unknown reason	***Processing***. The physical world is constantly in flux because processing creates it
Space. The canvas of space is seen as: a) *Empty*, but filled by fields and virtual particles b) *Continuous*, despite the Planck length limit c) *Complete* except for the imaginary dimension into which light vibrates d) *Expanding*, for no reason at all e) *Relative*, as each point has its own space frame	***A network***. A grid that transfers programs is: a) *Filled with processing*, even null processing b) *Discrete*, as a node is a point and an infinitesimal c) *Contained*, as a surface that can curve to carry the wave vibrations of light d) *Expanding*, like a bubble in a larger bulk e) *Local*, as each node "paints" its own links
Time. The flow of time is seen as: a) *Continuous*, despite Planck time b) *Modified*, by speed and mass for some reason c) *Defined*, by a sequence of static quantum states d) *Reversible*, in all the laws of physics e) *Relative*, so each point has its own time	***Processing.*** Time as the completion of processing is: a) *Discrete*, so Planck time is one processing cycle b) *Modified*, by the local processing load c) *Defined*, by a sequence of dynamic choice events d) *Irreversible*, as a physical event is a reboot e) *Local*, as each node cycles at its own rate
Empty space. Looks like nothing, yet it: a) *Manifests* non-zero energy for some reason b) *Spawns* "virtual" matter and anti-matter particles c) *Mediates* light, as a "wave of nothing" d) *Is limited*, as black holes expand with new matter	***Null processing.*** Gives no net output, yet it: a) *Is active*, so its output is only zero on average b) *Can split* into opposing processing cycles c) *Hosts* the processing of photon programs d) *Is finite*, with a black hole the node bandwidth
Spatial directions. Objects move in: a) *Straight lines* for some reason b) *Lines that gravity bends*, for some reason c) *In directions* that are continuous for every angle	***Network architecture***. Packets transfer along: a) *Least transfer routes* (straight lines) b) *That alter* with a load differential (gravity) c) *In directions* that are discrete for a quantum event
The big bang. The universe began as a big bang that: a) *Created itself*, from nothing b) *Was a singularity*, of the universe at a point c) *Expanded* like a bang, so cosmic back-ground radiation should be at the universe edge by now d) *Initially inflated* faster than light, due to a massive anti-gravity field that arose for no reason, and then vanished also for no reason	***The small rip***. The universe began as a small rip that: a) *Was created*, in a previously existing quantum grid b) *Was one photon*, in one volume of space c) *Expanded* like a sphere surface, so cosmic background radiation is still all around us today d) *A rip chain reaction* created all the free processing of our universe, until *the expansion of space* overpowered it, by diluting the first light

a node. Table 1 compares how quantum realism and physical realism see space and time, so the reader can decide for themselves. In one view, physical events in a bendable space flowing in a malleable time are a system complete in itself that once began, in the other quantum events created physical events and their space-time in the beginning and continue to do so today.

QUESTIONS

The following discussion questions arise from this chapter:

1. If the physical world is a virtual reality, what is the screen?
2. If the physical world is an image, what is its resolution and refresh rate?
3. Can the ongoing flux of our world ever stop?
4. If the reality we see is virtual, can we one day download and upload it?
5. How does a dimension “curled up” in space differ from one that is “wrapped around” space?
6. Is space something or nothing? If it is nothing, what transmits light? If it is something, what is it?
7. Would one expect a network simulating our universe to be centralized or distributed?
8. How is a hyper-sphere surface like our space?
9. If light moves by a grid transfers, what are "straight lines" in network terms?
10. If our time was centrally processed, could we know if it slowed down? What about a distributed system?
11. If time is a sequence of choices, can we run the choices backwards, i.e. roll-back time?
12. If our space is expanding, what is it expanding into?
13. If our universe once existed at a point singularity, why didn't it immediately form a black hole?
14. If time began at the first event, what made it begin? How can time itself “begin”?
15. Why is cosmic background radiation from after the first event still all around us, instead of far away?
16. If the net processing of the universe is constant, where did it come from? Why doesn’t it change?
17. How do our networks deal with the asynchrony problem? How could a network with no buffers handle it?
18. How can quantum events that don’t exist predict physical events that do?

ACKNOWLEDGEMENTS

Especial thanks to Belinda Sibly.

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