Exploring the virtual reality conjecture *by Brian Whitworth*

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Introduction

Computers today simulate entire worlds with their own time, space and objects but that our world could be so is normally a topic of science fiction, not physics. Yet the idea that the world is illusory has a long philosophical history. In Buddhism, the world arises from a universal mind, in Hinduism it is Maya, the illusion of "God's play", and to Plato it was just shadows flickering on a wall[1]. That the world is digital has an equally long pedigree. To Pythagoras numbers were the non-material essence of the world. Plato felt that "*God geometrizes*" and Gauss that "*God computes*", as depicted in Blake's "Ancient of Days" (Figure 1). The tradition continues today, as Zuse argues that "space calculates" [1] and others ask if reality computes?[2]

Figure 1. God computes?

This essay explores the *virtual reality (VR) conjecture*, that the physical world is the digital output of quantum processing.

The existential hypotheses

The western contrast is between Platonic *idealism*, that the seen world reflects a greater unseen one, and Aristotelian *physicalism*, that what we see is all there is. Logically, one of these world views must be wrong. Yet after centuries of dispute, science and religion formed the truce of *dualism*, that mind and body realms *both* exist, dividing scientists into atheists who saw *only* the physical world, theists who *also* believed in a non-physical reality, and agnostics who didn't know.

Today, dualism seems increasingly a union of opposites, a marriage of convenience not truth. If different mind and body realms exist but don't interact, what relevance are they to each other? Or if they do interact, which came first? If a conscious mind "emerges" from a physical brain, isn't it superfluous? Or if the mind creates the body as in a dream, why can't I dream the body I want? Hence dualism is currently in retreat before the simpler, non-dual view *that there is only one real world*. Scientists observing this ideological war generally feel that if there is only one world, let it be the physical one that we study.

If everything is physical, then quantum computing for example must also be physical.[3] If so, could a physical universe compute itself? Yet logically a reality cannot entirely output itself [3 p6], as how could the process ever begin? So if the physical universe is the output, *what is the computer?* Or if it is the computer, *what is the output?* A physical universe can no more output itself than a physical computer can print itself out[4]. A simulated reality cannot be complete in itself. As in our simulations, something external must exist to sustain it[5].

The traditional existential options are:

a) *Physicalism.* That only the physical world exists.

b) *Solipsism*[6]. That it is all just a mental illusion.

c) *Dualism.* That another reality exists beyond the physical.

Yet logically, another "one-world" option remains, namely *virtualism* [6], that only the "other" reality exists. In this admittedly radical view, the "ghostly" world of quantum theory is the real world and our physical world is just an image on a screen thrown up. This doesn't, as some naively think, imply "hardware" in a metaphysical realm. The quantum world is quite unlike the physical world we know: quantum states disappear at will so are not permanent like matter. Entangled quantum entities ignore speed of light limits on physical movement. Superposed states exist simultaneously in

physically contradictory ways. The quantum world is *physically impossible*, so physicality cannot be the yardstick of its reality.

A physical world created by quantum processing contradicts the "prime axiom" of physics:

There is nothing outside the physical universe [7].

The VR conjecture implies its antithesis, that:

There is nothing inside the physical universe that exists objectively, i.e. of or by itself.

That *this* world is an objective reality or a virtual reality are mutually exclusive hypotheses. If science finds that the physical world *cannot* be an objective reality, it must consider the possibility that it is a virtual one.

The evidence

We know how simulations behave, so does our world behave like one? Here are ten reasons to suspect that the physical world is a simulation:

1. *The big bang.* That our universe arose from “nothing” in an initial time zero event makes no sense for an objective reality but it is true that every virtual reality boots up from “nothing” with respect to itself.
2. *The speed of light.* An objective reality has no reason for a maximum speed, but every simulation screen has a maximum refresh rate that limits local transfers.
3. *Planck limits.* An objective space has no reason to be discrete, as our world seems to be at the Planck level but a virtual space, being digital, must be so.
4. *Non-locality.* Effects that *instantly* affect entities *anywhere* in the universe, like entanglement and quantum collapse, are impossible in an objective reality but a program can alter pixels anywhere on a screen, even on one as big as our universe.
5. *Malleable space-time*. That mass and movement alter time and space is weird for an objective reality but a massive body in a virtual reality could use up grid processing around it to dilate time and curve space.
6. *Randomness.* If every physical event is predicted by others, a random quantum event is an impossible "uncaused cause" but a processor creating a virtual world can cause “random” events with respect to that world.
7. *Empty space is not empty*. In an objective reality empty space is "nothing at all" but in a virtual reality it is just null processing, and that can spawn the virtual particles that explain the Casimir effect.
8. *Superposition.* Quantum entities can simultaneously exist in physically opposite states, e.g. spin in two directions at once. An objective reality cannot do this but an information-based entity can divide itself to explore every option[7].
9. *Equivalence*. That every electron in our world is *exactly* like every other[8] is untenable for an objective world but simulations always use program templates for basic entities.
10. *Quantum tunnelling.* An electron "tunnelling" through an impenetrable field barrier, like a coin popping out of a perfectly sealed glass bottle, is impossible for objects that continuously exist but not for a simulation based on discrete event frames.

Each of the above is fundamentally *impossible* for an objective reality but not for a virtual one. The physical evidence is that our world behaves like a simulation, so by the duck principle:

If it looks like a duck, and quacks like a duck, then it is a duck.

Do we then live in the Matrix? In that movie, people only knew their reality by the information it gave them, much as we know ours. Only when a pill disconnects the hero from his input does he fall back into the real world where physical machines are farming people's brains in vats. The virtual reality conjecture is the *opposite idea,* that the physical world is just the simulation and what creates it is a non-physical quantum world that we don’t fully understand.

Nor is this *solipsism*, that the physical world is just a dream, which Dr Johnson is said to have refuted by stubbing his toe on a stone, saying "*I disprove it thus*". The virtual reality conjecture is again the *opposite idea*, as it accepts that there is a quantum reality "out there", apart from us. It just gives that world non-physical properties.

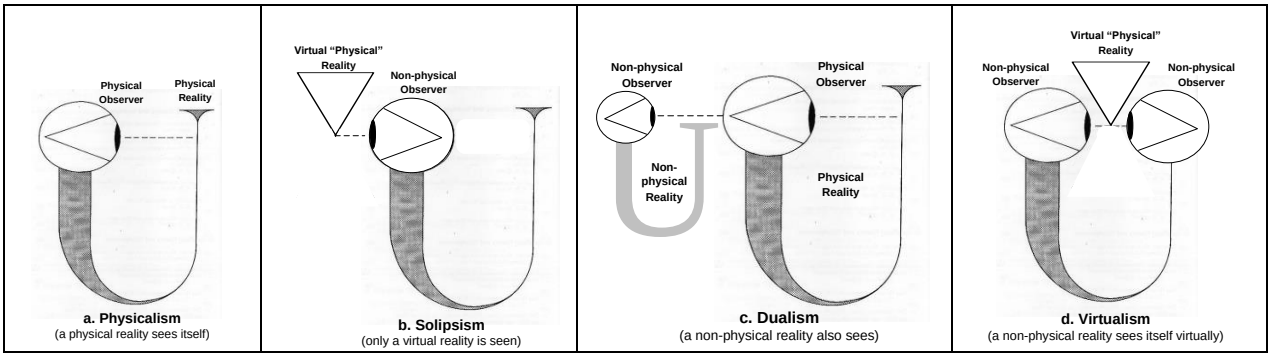


Figure 2. Universal (U) models

Figure 2 shows the options. In *physicalism* (2a), a self-existent physicality sees itself when consciousness mystically "emerges" from it [9]. In *solipsism* (2b), a self-existent consciousness imagines a dream world that doesn't really exist at all. In *dualism* (2c), a self-existent physical world has a self-existent higher reality observing it. In *virtualism* (2d), a self-existent but non-physical reality experiences itself using a virtual reality that, like a game reality, has no inherent existence. Yet to an avatar within this *local reality* its events are as real as it gets, i.e. stubbing a virtual toe still hurts.

In the last option, the virtual reality conjecture, the physical world is virtual but the *observer* is not, so it can underlie consciousness[9]. This is no unreal dream universe, with us its existential centre, if *everything* is "knowing" everything else[10], like the most massive of online multiplayer games. The rationale of a system that simulates itself to itself cannot be properly put here[11], but is essentially that there is indeed a real world around us - it just isn't the world we see.

The model

In computing, information depends on the finite number of discrete choice options[12] [10] and *processing* transforms information, i.e. makes a new choice. If the physical world is virtual, we should be able to *reverse engineer it*, i.e. derive time, space, energy, light and matter from processing.

Figure 3. A virtual reality

The processing grid

As argued, a simulated world requires a network to produce it, which Wilczek calls:

"*the Grid, that ur-stuff that underlies physical reality*" [11 p111].

This grid is envisioned as a logical network whose nodes dynamically link to each other, like a cell-phone grid, but passing dynamic instructions not static data. A photon then is a *program* telling grid nodes to set quantum state *pixels*. Its instructions are passed between nodes as *packets*. Each node runs the packets it receives from others by the computing technique of "instantiation"[13], then divides its packet among *all* its neighbours, so quantum waves spread like ripples on a 3D pond. All light, energy and matter are proposed to arise from grid activity, with black holes being the grid at maximum capacity.

Each node has a finite capacity, so packets from different programs can overload it[14], i.e. "collide". A photon arrives at a detector screen as a "cloud" of distributed processing packets[15]. Each then requests processing from grid nodes already busy processing the matter of the screen. When those nodes overload, they reboot, i.e. try to re-read all their processing from scratch. The first *single* grid node to re-initiate the *entire* photon program is the point where it "hits" the screen[16].

The grid restart node is random[17] to us, as it depends on which node the program services first. The restart allocates all the photon program's instructions to one node cycle, so all other distributed packets instantly "disappear", i.e. quantum collapse is just the inevitable disbanding of extant packets when the program supporting them restarts anew [8].

The model also accommodates relativity, as if the avatars of Figure 3 are just pixels then so is their background. *No fixed node-pixel mapping is needed,* as programmers can "move" an avatar through a forest by bit-shifting image pixels across the forest or by bit-shifting the forest pixels behind the image. An avatar can stay centre-screen yet "move" through a forest that is scrolling behind it, i.e. have a constant relativistic "frame-of-reference"[18].

The grid proposed is not space, time, energy or matter *but what creates them*. Empty space is just the grid on "idle", like a screen that is blank but still "on". Turning it off, to show the screen (grid) itself, would also destroy the images on it (us). If quantum programs create the physical world, can we "hack" into them? Quantum computing is already doing just that.

Imagine looking out a window. One can only see the glass if it has flaws, by the frame around it, or by touching it. Now suppose a perfect transmitter with no flaws, that is all around so it has no frame, and that transmits matter so one can't touch it. Like a perfect diamond, the grid endlessly and flawlessly reflects the images of physical reality within itself.

Time as processing

While objective time passes inevitably by its own nature, virtual time passes by processing choices, e.g. in Conway's "Life" (Figure 4) pixels live and die by program events. A game that ran in twenty minutes on one computer could run in two seconds on a faster one but an avatar in both games would see the same virtual time pass if the same number of processing events occurred. We measure our time this way, as atomic clocks count atomic events. In the twin paradox a twin on a rocket accelerating to near the speed of light returns a year later to find his brother an old man of eighty, i.e. his time slowed down. In this model, his movement used up grid processing, leaving less to process his life's events, compared to his twin on earth.

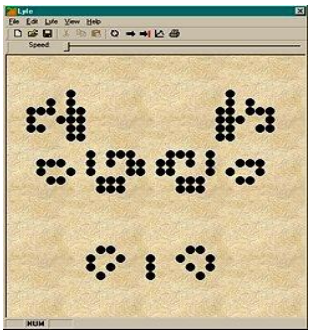


Figure 4. A Life simulation[19]

So time stops entirely for light because before a node can "tick" a processing cycle, the photon moves on. When people hear that time slows down they suspect an intellectual trick but it is no trick. In particle accelerator experiments, time really does slow down. It is not *perceptions* of time that change but *actual time*, as measured by instruments. Only in a virtual reality, where time is the *local* number of processing events measured, can this be.

Space as processing

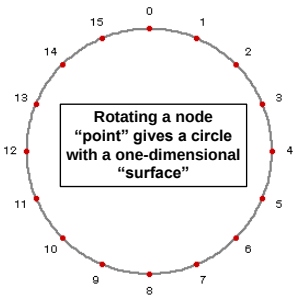


Figure 5. One-dimension

Continuously dividing a simulated time gives a "tick" which cannot be paused and continuously dividing a simulated space gives a "pixel" which cannot be split. In our world, studying Planck length or time needs short wavelength light, which is high energy light, but putting too much energy into a small space gives a black hole, which hides information from us. Probing a black hole with more energy just increases its size, to reveal no more. Just as closely inspecting a TV screen reveals only dots and refresh cycles, so closely inspecting our world reveals its resolution and refresh rate[20]. A digital universe of irreducible pixels and indivisible ticks resolves the *continuum problem* that has plagued physics since Zeno first outlined his paradoxes[21].

Loop quantum gravity, cellular automata and lattice simulations [12] map nodes to points in a *static* Euclidean space, but relativity requires that nodes be allocated to points *dynamically,* as the Internet allocates IP addresses - on demand.

A finite set of "mini-CPU" nodes can form a dimension by arbitrarily linking up into a circle, so each node can transmit in left and right "directions" (Figure 5).

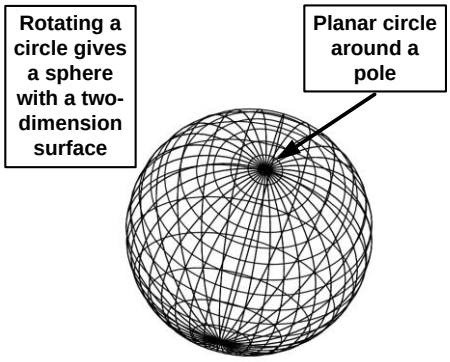


Figure 6. Two-dimensions

Repeating the notional rotation, gives a discrete sphere with a two-dimensional surface (Figure 6). A *pole* of this sphere has a *planar circle* of nodes around it to define its "directions". Yet the rotation axis making that node a pole was arbitrary. Choosing a different axis lets another node be a "pole" on the same sphere surface. Networks can easily alter links, so let *each node locally configure itself as a pole,* by setting its local links so. Now by rotational symmetry, *every* node has a planar circle of neighbours veridical to directions on an ideal sphere *with itself the rotation origin*. Each node can "paint" its own longitudes and latitudes when activated, i.e. define its own space.

Figure 7 just repeats the process for another dimension[22]. As rotating a circle gives a sphere so rotating a sphere gives a *hyper-sphere* whose *surface* is unbounded, simply-connected and three-dimensional - just like our space[23]. Its *granularity* is the number of discrete steps in the N-rotation creating it, where a triangle is a "3-circle", a square a "4-circle", etc (Figure 8). Yet with N large, discrete circles cannot tessellate a surface, i.e. this space has "holes" in it. Point entities like electrons could pass right through each other. Luckily, quantum entities in our world exist over an area, so are at the "same point" if in the same vicinity. *That quantum entities exist inexactly lets an inexact, non-Euclidean space simulate ours.*

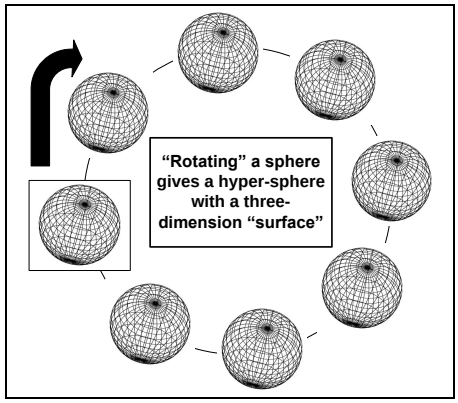


Figure 7. Three-dimensions

A node on a three dimensional hyper-surface has a sphere of neighbours, but that *all grid transfers use planar circles* is not unthinkable, as quantum Hall models use two-dimensional *anyon* excitations to derive quantum events [14]. In this model, one node has many planar transfer channels, where a photon polarized in a plane uses one channel. That discrete planar circles define directions predicts there is be a minimum *Planck angle* for single node quantum events [5][24].

Implications

The big bubble?

An objective universe that "just is" may transform its parts but its total *steady state* shouldn't change. So last century, big bang theory battled it out with respected physicists for whom a steady state physical universe just "popping up" out of nowhere was highly unlikely. Yet if all the galaxies are expanding out from us at a known rate, there must have been a source event about 14 billion years ago. Finding cosmic background radiation left over from the big bang has confirmed it for most physicists today.

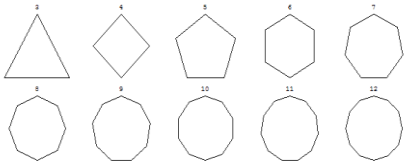


Figure 8. Discrete rotations, N = 3-12

The failure of steady state theory removes a cornerstone of support for the idea of an objective universe that exists in and of itself. Physics today "defines away" questions like "*What existed before the big bang?*" as irrelevant, but any universe that *began* is dependent, so what it depends on is a valid question. Could a time and space that suddenly appeared, for no apparent reason, equally suddenly disappear today? If nothing in the universe comes from nothing, how can the entire universe have done so? That an objective physical universe *arose from nothing* is not just incredible, it is inconceivable.

In contrast, this model *requires* a big bang. Every virtual reality starts up with a sudden information influx that begins *its* space and time. Anyone who boots up a computer starts a "big

bang", before which there was indeed "nothing" (in computer memory) nor did *its* "space" or "time" exist. Here, the big bang was just when our universe booted up.

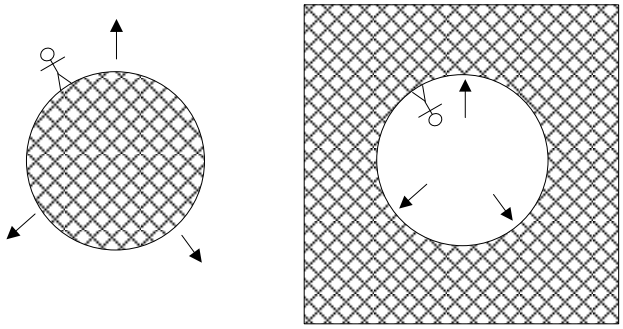


Figure 9a. The Big Bang, 9b. The Big Bubble

The term "Big Bang" puts us *outside* an expanding sphere (Figure 9a) but perhaps we are *inside* a bubble, or hyper-bubble, expanding into the bulk around it (Figure 9b)[25]. Space as a hyper-bubble surface is unbounded but finite and expands but has no centre, just like our space. Its expansion isn't evident because it doesn't alter existing matter - the bulk fills only the "gaps" that arise everywhere. An explosion on such a surface will first go "out" then wrap around to end up everywhere. So cosmic background radiation is still all around us, not at the edge of some objective universe, because it has circled the universe many times.

Light as processing

Does an extra dimension plus four dimensions of space-time give five dimensions in all? In this model the dimensions of time and existence are one and the same, so it has only four degrees of freedom: three for space and one for *existence in time*. It supports the Hartle-Hawkin no-boundary theory: that at the big bang one of four equivalent dimensions "somehow" became time while the other three formed space [15]. Here, that somehow was as the dimension into which quantum wave-entities oscillate to exist. Indeed, without such an extra *space-like* dimension, how can our space "curve", as relativity says it does? If light waves move *on* space, as water waves move on a pond surface, they can never leave it. We register them only because we exist in the same way that they do[26].

Conversely, that a photon exists as a "thing in itself" poorly explains its behaviour as a wave vibrating in a medium. Without a physical "ether", physicists must just *declare* that light vibrates "nothing"[27]. Yet vibrating nothing to create something makes no sense.

Light is said to be a "*... self-renewing field disturbance*." [11 p212], begging the question of what renews the fields that renew? That an electric force powers a magnetic force that powers an electric force, etc., is like Peter paying Paul's bill and Paul paying Peter's bill, etc. Were this possible, I could borrow a million dollars today and never have to pay it back[28].

Do light waves oscillate in space, as sound waves do in air? An objective realist might say how else could it be? Yet while empty space has no sound, it still transmits light, or we couldn't see the stars at night. So how can vibrating nothing have a physical direction as light does? And as space can't distinguish direction, with "up" from one view being "down" from another[29], how can an oscillation in space give the positive-negative valences of electromagnetism? The current view of light as a *frictionless wave vibrating nothing in no particular direction* is quite implausible.

In contrast, if light is processing wave, it "oscillates" frictionless information values in an ever-active grid network. The plus-minus values of electro-magnetism are then the in-out values of a logical hyper-surface, like bumps and dimples on a ball. The constant speed of light in a vacuum is just the grid network cycle rate, just as every screen has a refresh rate. In this view, the speed of light is just one transfer per node cycle. Light slows down in glass because the matter of the glass uses up local node processing. We *say* the medium of light is space or glass but in this model its medium is *always* the grid[30].

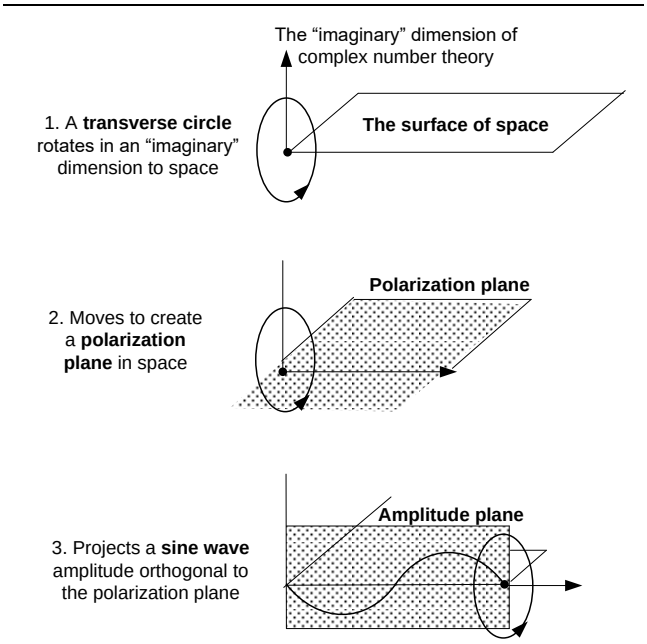


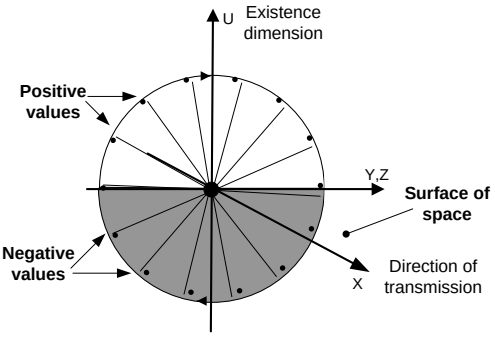
Figure 10. The sine wave projection

amplitude of light we see (Figure 10)[31].

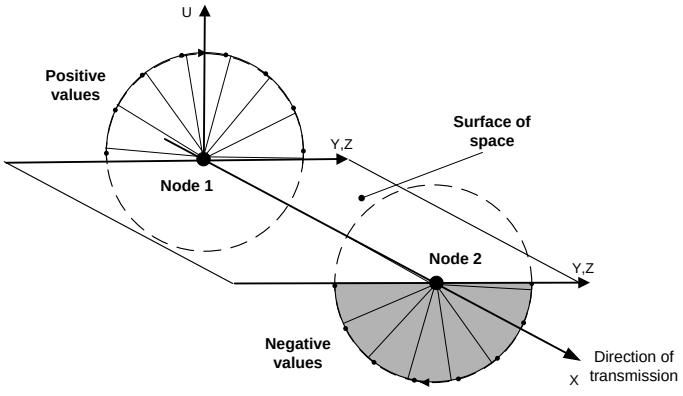
The grid also keeps photons in sequence, like the baggage cars of a train driven by the same engine. If the engine slows down under load, as when near a massive object, photons go slower *but still keep the same order*, so no photon can overtake another. Were it not so, we could see an object leave then arrive! Our causality depends critically on photons keeping in sequence, which the grid processing engine rigorously maintains.

The Planck program

In computing, a central processing unit (CPU) runs a program to tell screen nodes to set the pixel values of an image. Here the grid is both "screen" and "CPU" in our terms, as its nodes both receive input and generate output. The basic grid operation "adds one" to a discrete rotation turning in a *transverse circle* outside space. The set of instructions to turn a full transverse circle is here a *Planck program.* As it moves, it projects the sine wave



a. *Empty space*: A Planck program



b. *First light*: A Planck program splits

Figure 11. Processing space and light

Imagine a carnival wheel of black and white values spun by a pulsing machine[32], giving a "state" each turn (Figure 11a). The pattern spun is the program, the machine turning it the grid node and the net effect a world pixel[33]. If a machine turns a full pattern, the black and white parts cancel, as equal positive-negative values give zero, or as equal up-down displacements nullify. So one node running one Planck program per cycle is null processing, i.e. empty space.

But if the same pattern divides over two machines (Figure 11b), each shows first white then black, so the effect is no longer null. Something now “exists”, if only for one cycle. The *wavelength* of this highest frequency light is two grid nodes and its *frequency* is half the one-node frequency of space.

The rest of the electro-magnetic spectrum arises as the same Planck program divides among more grid nodes, increasing its wavelength. If no instruction is allocated twice[34], more nodes in a wavelength running the same Planck program lets each process at a slower frequency[35].

If *energy is the node processing rate*, it then comes in discrete packets because each higher frequency is one less grid node to run the same program. So the highest photon frequency will have a

wavelength of two Planck lengths and must *double* its energy to reach the Planck energy of empty space[36]. Also, every photon has zero *rest* mass because it actually is space spread out - if it ever "rested" for its wave train to catch up, it would revert back to empty space.

Inflation

Suppose in the initial event *one* node "separated" leaving a “hole” in the grid, across whose inner surface it “moved”, as a transmitted processing wave[37]. This rip at first spread rapidly, like a tear in a taut fabric, giving a cataclysmic chain reaction[38]. So physicists extrapolating the universe's expansion backwards find that for a brief period, called *inflation,* it expanded faster than light [18]. In this model, *inflation was the grid itself ripping apart to create the physical universe simulation.*

However the "hole" created also expanded rapidly, weakening the waves on its surface and stopping the chain reaction [8 p17]. Today the ripping has stopped but space still expands and the vibrations on its surface continue. Diluted by the expansion of space, they have descended into lower and lower frequencies, from gamma rays to radio-waves (Figure 12).

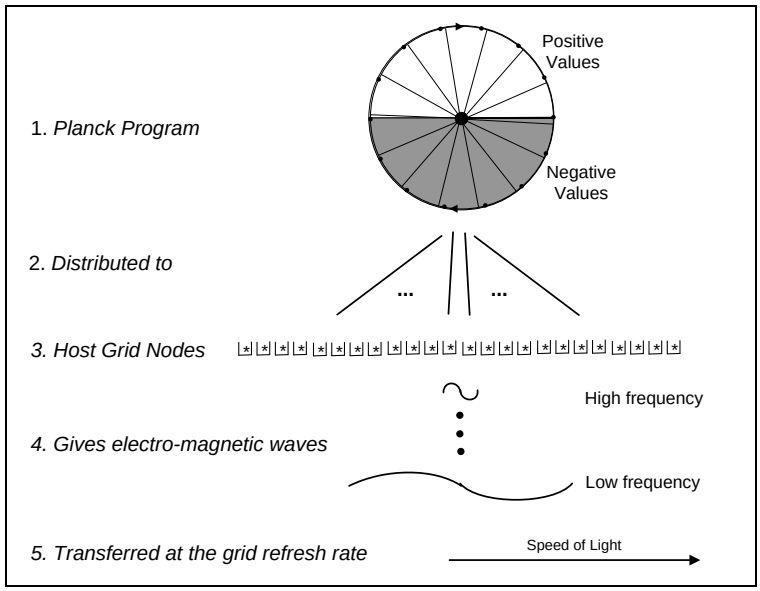


Figure 12. The electro-magnetic spectrum

This explains why the big bang didn’t immediately form a black hole, as a "big crunch" would, because the universe wasn't created all at once. In this model, there never was a point "singularity", as the universe began as *one* photon in a unit *volume* of space. An unimaginable chain reaction, that will never repeat, then created the rest of our universe as quantum waves on the surface of space[39] [29]. So since inflation, the free information of the universe has always been constant.

The size of space

Plank’s constant, the unit of photon energy, also *defines the size of space:* if it were smaller atoms would be smaller and if it were larger quantum effects more evident. Why does the same value define both energy and space?

In this model, grid nodes process a *transverse circle* of values whose number defines Planck’s constant. It is also proposed that a *planar circle* connects nodes to define the directions of space, each being a transfer "channel". The number of channel connections around a node defines a circumference and hence the radius between grid nodes [5]. If the grid is symmetric, transverse and planar circles have the same size, i.e. the same number of nodes. Planck's constant links the quantum of energy and the size of space because it is the granularity of the grid that defines both.

Anti-matter

If the laws of physics are reversible[40] why isn't time? In this model, time is not a sequence of static states[41] but a sequence of processing cycles[42], so we live in a world of choices not "things". The processing sequence can then run in reverse to give anti-matter because all the choices are reversible. However if quantum collapse is a processing restart, it is irreversible, as a reboot loses all previous data. So no quantum *interactions* can be reversed[43].

However, *in between interactions* the "add-one" processing of existence can be reversed[44] to give an "opposite" existence, i.e. anti-matter. In Feynman diagrams anti-matter particles enter events going backwards in time. This does not mean anti-matter can reverse its physical interactions, any more than matter can,[45] just that it processes its existence in the opposite direction. It runs *our* virtual time backwards, but in *its* virtual time, it is our time that is running backwards. If the difference between

processing matter and anti-matter is the cycle direction, the node split that began the universe was the "symmetry breaking", in that it gave a matter rather than anti-matter universe[46].

Conclusions

Relativity and quantum theory contradict not only common sense but also each other:

1. *Quantum theory* assumes an objective space background which relativity specifically denies. For quantum theory to satisfy relativity it must be *background independent,* i.e. not assume, as it currently does, that quantum states arise in a fixed space or evolve in a fixed time [21].
2. *Relativity* assumes objects exist locally which quantum theory specifically denies. For relativity to satisfy quantum theory it must be *foreground independent,* i.e. not assume, as it currently does, that objects exist in fixed localities and travel fixed trajectories.

These theories clash because each denies an objective reality assumption the other accepts[47]. In the virtual reality conjecture, *both foreground objects and background space-time are processing outputs,* i.e. virtual.

Indeed, a world of objects that inherently exist is a concept flawed at its foundation. If a photon is a mini-object with hidden parts, they need still finer parts, and so on. If every physical object contains smaller objects, how can it ever end? That physical objects always arise from other physical objects is like the earth being a disc on the back of a giant turtle. Just as that turtle would need another turtle to stand upon, ad infinitum, so every object would need sub-objects to comprise it. A universe can no more be “objects all the way down” than it can be “turtles all the way down”[48]. The existential buck has to stop somewhere, and in this model, the quantum processing cycle is it.

By the logic of quantum theory, between our "real" observations is a quantum unreality of which the Copenhagen doctrine says *we must not speak*. Yet as entities are in-between interactions more than in them, the world exists mostly in uncollapsed quantum states. So by what logic are its brief moments of collapse "real"? *Surely reality is what exists most of the time?*

Or if quantum waves predict and cause physical reality, isn’t making a cause "unreal" and its effect "real" backwards logic, like saying the sun circles the earth? If quantum states create physical states, by what logic are they unreal? *Surely reality is that which causes, not that which is caused[49]?*

The denial of quantum reality by physics is doctrinal not logical[50]. This *faith* in physicality is held despite facts and logic, in denial of the evidence that quantum states are non-physical by nature and quantum collapse is non-physical by origin. Equally, when matter was first attributed to unseen atoms some scientists at first denied it[51]. Then even smaller electrons, protons and neutrons were found inside atoms, and now science even accepts quarks that are forever unseeable. Yet when quantum theory says that the answer to everything is a numerical probability[52], we cry “*Enough!"* This it seems is a step too far.

The virtual reality conjecture takes us to this place that others avoid, not to shock or amuse but to progress. We suppose ourselves in the rational sunlight of physical reality, standing before a dark cave of quantum paradox, but in this model, as in Plato’s cave analogy, it is the other way around. We sit in the dark cave of physicalism with our backs to the quantum sunlight watching the virtual shadow world it projects for us.

The virtual reality conjecture is neither illogical nor unscientific, nor does it say the world is fake. It is compatible with current physics[53] and also predicts new things about space, time and the universe. If it is true, then our reality must be fundamentally digital.

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[1] In the analogy, people are tied up in a dark cave with their backs to its exit. Looking at the cave wall, they see their shadows, created by sunlight from the outside, and take those projected shadows as their reality.

[2] For example, Fredkin, Lloyd, Tegmark, Campbell, Svozil and Wolfram.

[3] For example: "*Imagine the quantum computation embedded in space and time.*" [2] p172.

[4] Biological properties can evolve by autopoietic bootstrapping but existence itself cannot arise the same way. No amount of "emergence" deriving from the interaction of existing parts can create something from nothing.

[5] McCabe argues that the physical world can't be simulated as follows: "*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*" [4]. The logic is correct for static data which needs a viewer context, but not for the dynamic information of this model, which doesn't. See [5] p5 for details.

[6] Berkely developed solipsism from Platonic idealism. It is also called nihilism in eastern Buddhist philosophy.

[7] Distributed entity processing can account for the law of least action, see [8] p19.

[8] By the quantum *indistinguishability* principle, it is impossible to mark any electron apart from another.

[9] In science fiction terms, *we are the aliens* creating a virtual reality from outside it.

[10] So quantum collapse is not just if we observe the world but if anything does, i.e. any quantum interaction.

[11] In physicalism, things are not conscious. This model is the opposite, as in it *everything* is "conscious". All that distinguishes us from say a rock is that we can become aware of the consciousness that is everywhere.

[12] Information $I = Log_2(N)$ for N *finite* options in a choice. So an information universe must be discrete.

[13] Instantiation of an entity class is an object orientated systems (OOS) method by which identical information "objects" dynamically inherit code from a single program blueprint, e.g. screen buttons instantiating the same class all run the same code. The class can dynamically feed code to its many instances on request.

[14] Actually, a node planar channel overloads, where a channel is a plane through a node. See [8] p 23

[15] Distributed processing allows Huygen's principle, that each *wave front point is a new wavelet source expanding in all directions*. Except a processing wave can also restart at a point, like a particle.

[16] This doesn't repeat the overload because nodes first share and then process. See [8] p16 for the details.

[17] We call it random because it depends upon no previous physical event.

[18] Only at a particular processing cycle does one space "point" necessarily map to one grid node.

[19] See http://abc.net.au/science/holo/lablife.htm.

[20] Planck length of 10^{-33} meter is the pixel resolution and Planck time of 10^{43} second is the refresh rate.

[21] These are:

a) 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 it was, the tortoise has moved on.

b) 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. How can such instants beget movement?

To accept either one is to trip up on the other, i.e. without an infinity of points there can be no continuous movement. Or if there is an infinity of points, the hare can never catch the tortoise.

[22] So like Mr. A. Square of Abbot's Flatland [13], we struggle to imagine a dimension beyond our experience.

[23] One way to imagine a hyperspace is to think of our space but with every point a tiny sphere.

[24] If N is the grid granularity, the local Planck event angle is 360°/N.

[25] The inner surface of the hyper-bubble is in this model our space.

[26] In this model, lepton and quark matter arise as "standing waves" when meta-light tangles.

[27] For example: "… *we accept as nonexistent the medium that moves when waves of quantum mechanics propagate.*" [16] p56. This model in contrast does not accept this as reasonable at all.

[28] Some of course believe this is possible. See our explanation of the credit meltdown [17].

[29] Space is *isotropic*, i.e. all directions are equivalent. So it cannot generate positive-negative valences.

[30] The Michelson–Morley experiment denied the idea of a physical ether, but the idea of a non-physical ether has never been contradicted. Indeed that space is filled with an invisible essence has waged a vigorous comeback.

[31] If our space is a surface, light really does oscillate into an "imaginary" dimension outside "real" space, as complex number theory says. In this model, the mathematics is not just a "convenient fiction".

[32] The physical analogy is to help understanding only, and should not be taken literally.

[33] In this model, a pixel is a quantum state.

[34] The principle of conservation of processing is that every entity program instruction is always allocated to run on the grid. It is proposed to underlie all our partial conservation laws.

[35] In current physics, $\boldsymbol{E.\lambda = h}$, with E energy, λ wavelength and h Planck's constant. In this model, that the total processing of the wavelength (Planck's constant) equals the processing rate per node (energy) multiplied by the number of nodes (wavelength) is self-evident.

[36] This bears on what physics calls the "hierarchy problem".

[37] In this model, the inner surface of the grid "hole" began our space and the "first photon" began our universe.

[38] In this model, a packet transferred once per node cycle travels at the speed of light. In inflation, each transfer immediately "rips" the receiving node apart before it can process any cycle. So this chain reaction occurs at the node transfer rate, i.e. much faster than the speed of light.

[39] It is the *interaction and overload* of these processing waves on the grid that simulates our physical world.

[40] Including the equations of quantum mechanics.

[41] In what Barbour calls a "time capsule". He argues that states must exist in a "timeless" universe [19].

[42] In a "*Physics of Now"* [20] p101, each "state" is equivalent to another choice.

[43] This includes all "observations".

[44] The basic grid existence operation, which is to "add one" to a transverse rotation, is asymmetric with respect to the hyper-surface, i.e. one can also "subtract one". Only if existence is processing can it be run in reverse, as anti-matter does.

[45] This model preserves the causality and unpredictability that the following paradoxes demand:

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

Time as grid processing is causal and events as node reboots are unpredictable, i.e. there is no time travel.

[46] The first value in the forward direction can be "out" or "in" with respect to a sphere surface. This choice defines the "matter" of our universe, leaving "anti-matter" just a possibility. So there is no need to wonder "Where did all the antimatter go?" as current physics does. It didn't go anywhere because it never was.

[47] In the story of the stranger, a father and son boarded a train and had meals where another man congenially joined in and ate their food. When the father asked the son "Is he your friend?" he replied "Wasn't he your friend?" The stranger then took off and was not seen again. The story shows how assumptions install themselves.

[48] In this apocryphal story, a scientist lecturing that the universe depended on nothing outside itself was challenged by a little old lady who said it sat on the back of a giant turtle. He laughed, and asked her what the turtle was standing on, but got the reply "*Sonny, it's turtles all the way down*".

[49] As Penrose says: "*How, indeed, can real objects be constituted from unreal components?*" [22] p313

[50] The nineteenth century doctrine of positivism has become a religious canon. Yet science is a way to study reality not a belief about it. It is a way to ask questions not set of answers.

[51] For example, Ernst Mach denied that atoms existed.

[52] In Douglas Adams "The Hitchhiker's Guide to the Galaxy", the computer Deep Thought after millennia of calculations found that the answer to life, the universe and everything was 42. It was, of course, a joke.

[53] And its equations, which are then just the mathematical expression of the program logic outlined.