Article

The Nature of Reality in a Nutshell (Part I)

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Abstract

Reality is characterized by four aspects of reality: (1) forms of information, (2) the flow of energy, (3) perceiving consciousness, and (4) the Source of information, energy and perceiving consciousness. The scientific framework for this characterization is discussed in terms of the holographic principle, non-commutative geometry, an observer-dependent cosmic horizon arising in de Sitter space with a positive cosmological constant, and the one-world-per-observer paradigm. In this scenario, the observer is present at the central focal point of a cosmic horizon that arises in the observer's frame of reference, acts as a holographic screen, and projects the observer's space-time geometry. A consensual reality shared by many observers is possible if their respective horizons overlap. This scientific framework can only explain the nature of forms of information and the flow of energy. This leaves us with the quandary of how to explain perceiving consciousness and the Source. An argument is made that perceiving consciousness can only be understood as a focal point of consciousness that is differentiated from the Source and arises in relation to a holographic screen, in which case the Source can only be understood in the non-dual sense of an empty space of potentiality or a void of undifferentiated consciousness.

This is Part I of the two-part article (the references are listed at the end of Part II).

Keywords: Reality, information, energy, consciousness, Source.

To fully understand the nature of reality, it is only necessary to understand four aspects of reality: (1) forms of information, (2) the flow of energy, (3) perceiving consciousness, and the (4) Source of information, energy and perceiving consciousness. Once we've understood the nature of these four things, the problem of the nature of reality is solved.

The basic problem is everything we observe in the world is a form of information, like an image displayed on a computer screen. Computer generated images are always composed of bits of information. Information is encoded on the computer screen in a pixelated way, with each pixel on the screen encoding a bit of information in a binary code of 1's and 0's. A bit of information is typically encoded at a pixel by an on/off computer switch located at that pixel that is either in the "on" or the "off" position. The way information is encoded on the screen defines the images that are displayed and observed on the screen.

These images are animated over a sequence of events, just like the animated frames of a movie. When a movie is displayed on a computer screen, each event in the animation is a screen output. With each screen output, images are defined on the screen by the way bits of information are encoded on the screen. The animation of those images corresponds to a sequence of screen outputs. This animation of images over a sequence of screen outputs always occurs in the flow of energy, which is the power that energizes the computer.

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The animated images displayed on the computer screen are projected to the point of view of an observer. With each screen output, the images are projected to the point of view of the observer, who observes those images. The animation of images is observed over a sequence of screen outputs, which occurs in the flow of energy that energizes the process.

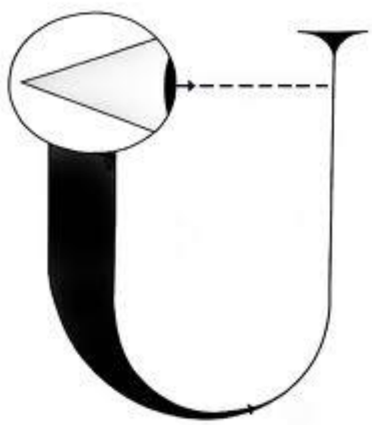


Image of Wheeler's universal observer from cosmoquest.org

How can this computer analogy give an accurate description of the world? The answer is found in two recent discoveries of modern physics and cosmology: the holographic principle [1] and the nature of an observer-dependent cosmic horizon [2]. When these two scientific concepts are put together, we discover that the world is just like a computer generated animation displayed on a computer screen and observed by an observer.

When we say everything we observe in the world is an animated form of information, like an animated image displayed on a computer screen, we are in effect defining the world on that screen. As we are about to see, the scientific concept that nicely explains the nature of this "animation of the world on a screen" is the holographic principle.

Not only does the holographic principle explain the "animation of the world on a screen", but it also explains the nature of the screen (as an event horizon), the encoding of bits of information on the screen (in the sense of the eigenvalues of a matrix, which are like spin variables that can only point "up" or "down", just like an on/off switch), the organization of bits of information into forms (as coherent organization that arises from entangled spin states or the entanglement of bits of information), and the flow of energy that energizes the whole animation process (in the sense of dark energy that gives rise to a cosmic horizon that inflates in size due to an instability in the amount of dark energy).

The only things the holographic principle cannot explain are the nature of the perceiving consciousness and the Source of information, energy and perceiving consciousness. If we understand the nature of the perceiving consciousness and its Source, the problem of the nature of reality is solved. The only problem with this solution is there is no scientific explanation for consciousness, and so there is no scientific explanation for the Source of consciousness. The problem of the Source cannot be solved scientifically.

The problem is there are no scientific concepts that explain the nature of the perceiving consciousness or its Source. The nature of the perceiving consciousness and its Source cannot be explained scientifically, and so science can never give us the complete answer. If we want to discover the complete answer, we have to look elsewhere.

The radical paradigm-shattering nature of this conclusion bears further discussion. The only reason we believe we are a part of the world we perceive is because we believe the individual consciousness that each of us possesses arises from our brain inside our head. Only that individual consciousness has its own inherent sense of being present, which is its own sense of "I-am-ness". When we call ourselves human beings, we are conflating that sense of being present with the human life-forms that we take ourselves to be. We mistakenly conflate our own perceiving consciousness with that perceivable life-form.

This conflating of the facts of existence is what neuroscience assumes, but then neuroscience has no idea about how consciousness arises from a brain, except for some mumbo-jumbo about "emergence". A few honest neuroscientists [3] admit they have no idea how perceiving consciousness arises. They admit it may not even be possible to explain how consciousness arises, and so they attribute its presence to be an "illusion".

The fact of the matter is, if the perceivable reality of a world composed of information and energy is the only reality, then perceiving consciousness must be an illusion, since it cannot arise as a part of that world. As long as the information that is organized in that world and the energy that flows through that world obey consistent computational rules, which we call the laws of physics that govern a world, then it is impossible for perceiving consciousness to arise within that world, no matter the degree of complexity with which information is organized or energy flows. On the other hand, if perceiving consciousness really does exist, then its existence must be found outside that perceivable world. If perceiving consciousness really does exist, then there must be another reality outside the reality of a perceivable world that is the Source of its existence. If we want to understand the nature of reality in its totality, then we have to understand the nature of the Source.

This odd state of affairs is best explained with the Gödel incompleteness theorems [2]. A human brain is a part of the human life-form. The best way to characterize the human brain is as a coherently organized form of information that is animated in the flow of energy. This is the case for any life-form we want to discuss. Any life-form is a coherently organized form of information composed of bits of information that tend to hold together over a sequence of events. This tendency to "hold together" or self-replicate form over a sequence of events is the nature of coherence. The sequence of events that define the animation of any self-replicating life-form always arises in the flow of energy.

No matter how we formulate the laws of physics that characterize any possible world within which any possible self-replicating life-form arises, those laws are only computational rules, just like the rules that govern the operation of a computer. With computation, bits of information encoded in a binary code of 1's and 0's are combined together with the rules of arithmetic.

The second Gödel incompleteness theorem [2] proves that any logically consistent set of computational rules as complex as arithmetic can never prove its own consistency. The "proof of consistency" is always found outside that set of rules. How then is it possible for a presence of perceiving consciousness to "know" about the logical consistency of the set of computational rules that govern the behavior of a brain if that brain generates that consciousness? The answer is: it is not possible. That presence of consciousness must be found outside the set of rules that govern the behavior of that brain or life-form, which proves that presence of consciousness is outside that brain and outside that life-form.

This state of affairs is really no different than the operation of a computer. The flow of energy that animates a life-form is no different than the flow of energy that energizes a computer, and a self-replicating life-form is really no different that an animated image displayed on the computer screen over a sequence of screen outputs. These images are observed each screen output as they are projected to the point of view of an observer outside the computer screen. The observer is always found outside the computer screen.

No matter how we formulate the laws of physics that characterize a world, these laws are only computational rules that govern how the bits of information inherent in that world are organized into forms and how energy flows through that world to animate those forms over a sequence of events. This is no different than the operation of a computer. The holographic principle tells us the observer is always found outside the holographic screen.

There can only be an illusion that the observer is defined on the holographic screen if the observer identifies itself with an animated image it perceives on the screen, as that image is projected to the point of view of the observer outside the screen. The nature of this illusion is the self-identification of the observer with the image of an animated life-form.

This raises the key question: what kind of reality is outside the reality of a perceivable world composed of information and energy when that world is defined on a holographic screen and the observer of that world is only a focal point of consciousness that arises in relation to the screen? The reason the holographic principle is able to point us to the only possible answer to this question is because a holographic screen defining an observer's world is a bounding surface of space that must arise in some "space of potentiality".

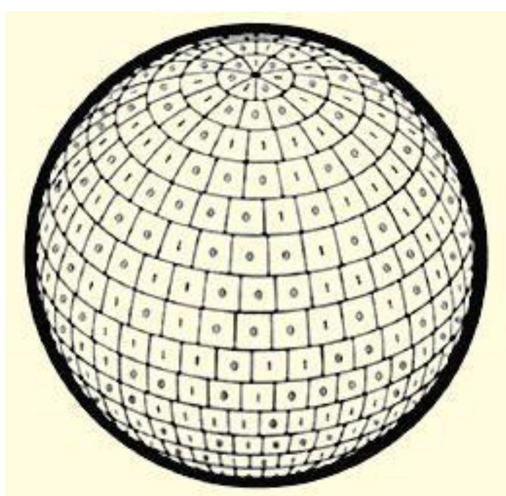
The space bounded by a holographic screen is not the ultimate nature of "space", but is only a holographic projection from a bounding surface of space to the point of view of an observer. The ultimate reality that is outside a perceivable world, which must be the Source of perceiving consciousness, can only be this "empty space of potentiality".

We also have the problem of space-time geometry, but this problem is also solved by the holographic principle. The space-time geometry of a world is defined by the projection of the images of things from a holographic screen to the central point of view of an observer over a sequence of events, where each event is like a screen output from a computer. The nature of space-time geometry arises from the spatial relations of the images of things projected to the observer's point of view and the temporal relations that arise over a sequence of screen outputs. In the language of relativity theory, the observer follows a world-line through that projected space-time geometry, and each observational event on the observer's world-line corresponds to a screen output that arises in the flow of energy, where the flow of energy naturally arises in the observer's accelerated frame of reference.

This description of a world in terms of forms of information defined on a holographic screen and the flow of energy that animates those forms is as far as physics can ever take us. The problem is physics can never explain the Source of the perceiving consciousness outside the screen, nor can physics explain the Source of the information and energy that allows a world to become constructed and displayed on a holographic screen. If we want a complete description of the nature of reality, we have to confront the problem of the Source, but physics and scientific theories can never give us the complete answer.

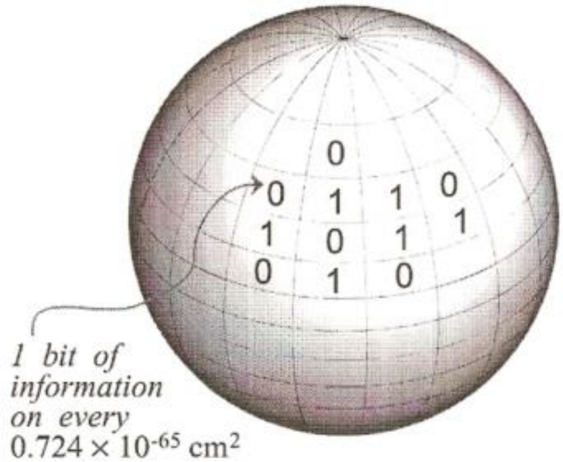
We could begin with the Source, which is only describable in physical terms as an empty space of potentiality, the void, or infinite nothingness, and then realize that for this "empty space" to be the Source of perceiving consciousness, it must also be describable as undifferentiated consciousness. In some unknown way, perceiving consciousness must be differentiated from its Source of undifferentiated consciousness. This differentiation process is somehow related to how all the information and energy that characterizes the observer's world arises from the Source as the observer's consciousness is differentiated from the Source.

Instead of beginning with the Source, we'll begin with the holographic principle and work backwards, and then infer how this principle implies the nature of the Source.



Horizon information image from eskola.hfd.hr

The holographic principle [4] tells us all the bits of information that define everything an observer can observe in its world are defined on a holographic screen. The holographic screen is a bounding surface of space that encodes all the bits of information that define all the observable things an observer can observe in the space limited by that bounding surface. Information is encoded on the screen in a pixelated way, with each pixel on the screen encoding a bit of information in a binary code of 1's and 0's.



Covariant entropy bound image from 't Hooft

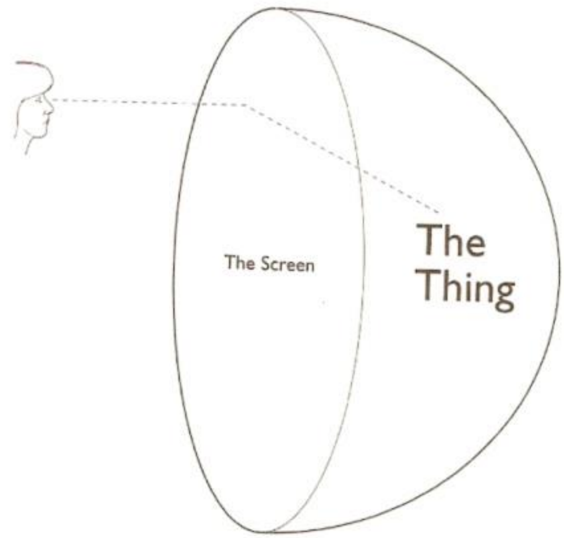
Modern physics tells us that each bit of information is encoded on a pixel defined on the screen, where the pixel size is about a Planck area, $\ell^2=\hbar G/c^3$. In the sense of a quantized space-time geometry, the Planck length ℓ, which is about 10^{-33} centimeters, is the smallest possible distance scale that can be measured [1]. This pixelated way of encoding information is the natural way to understand how a space-time geometry is quantized [5].

The holographic screen always surrounds an observer at the central point of view, and the observation of anything in that bounded space by the observer is like a screen output from the screen to the central point of view of the observer. This is just like the kind of observations an observer makes on a digital computer screen. With each screen output, the images of things are projected from the screen to the observer's central point of view.

Since all the observable images of things in the observer's world are projected from the screen to the central point of view of the observer, the observer can only be understood as a focal point of consciousness. This focal point of consciousness always arises in relation to the bounding surface of space that acts as a holographic screen. In the sense of the projection of images, the observer is always present at the central point of view.

Everything the observer can possibly observe in the space bounded by the screen is like the holographic projection of images from the screen to the central point of view of the observer. Although the bits of information are encoded on a two dimensional screen, the projected images appear three dimensional since they're holographic.

The holographic principle also tells us that the most generic way to understand how bits of information are encoded on the screen is in terms of matrices [2]. A bit of information corresponds to an eigenvalue of the matrix. Encoding bits of information in this way is very similar to how spin variables encode bits of information in quantum theory. We understand that spin variables can only point “up” or “down”, and so they encode information in a binary code of 1’s and 0’s, just like an on/off computer switch that is either in the “on” or the “off” position.



Holographic principle image from Smolin

The holographic principle [4] says all the quantized bits of information that characterize a region of space are encoded on a surface bounding that space, which is called the covariant entropy bound. The number of bits of information, n, is specified in terms of the surface area, A, and the Planck area, ℓ^2, as $n=A/4\ell^2$, as though the surface is covered with n pixels, each about a Planck area in size and each encoding a bit of information. These n bits of information are naturally defined by the n eigenvalues of an nxn matrix.

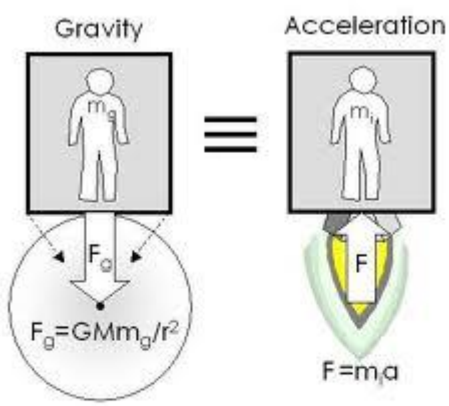
This way of encoding n bits of information on a bounding surface of space in terms of the n eigenvalues of an nxn matrix naturally arises in a non-commutative geometry due to the parameterization of spatial coordinates on the surface with non-commuting variables [6]. If the bounding surface of space is parameterized in terms of an (x, y) coordinate system, like latitude and longitude on the surface of a sphere, and if these spatial coordinates are required to act as non-commutating variables that generate an uncertainty relation of the form $\Delta x\Delta y\geq\ell^2$, then each point on the surface becomes fuzzy and is smeared out into an area element of size ℓ^2. Each area element acts like a pixel on the surface that encodes a bit of information that is defined by the n eigenvalues of an nxn matrix, where the value of n is specified in terms of the surface area, A, of the bounding surface as $n=A/4\ell^2$. The (x, y) coordinates, as represented by n non-commuting variables, no longer define points on the surface, but pixels. These n position coordinates are defined on the surface in a rotationally invariant way since the nxn matrix is typically an SU(n) matrix. Since an SU(2) matrix encodes information in a binary code of 1's and 0's, like spin variables that can only point "up" or "down", and since an SU(n) matrix is always decomposable into SU(2) matrices, the n bits of information are also encoded in a binary code.

In quantum theory, spin variables are represented by matrices, and so it is natural to understand how a holographic screen encodes bits of information in terms of matrices. Each eigenvalue of the matrix is like a bit of information that encodes information in a binary code. In the sense of quantum entanglement, the eigenvalues of a matrix are all entangled with each other, and so all of this information is entangled.

This entanglement of information allows for coherent organization of information, which allows forms of information to self-replicate their forms over a sequence of events, where each event is like a screen output that projects images of things to the observer's central point of view. The self-replication of form follows from the entanglement of information.

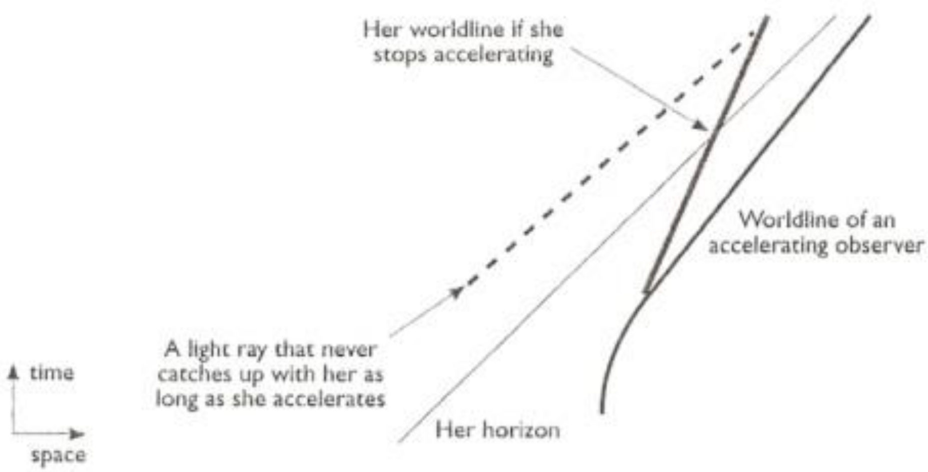
The images projected to the observer from a holographic screen are best understood in the sense of coherently organized forms of information. These coherently organized forms of information can be understood in the sense of bound states of information that tend to hold together over a sequence of screen outputs. Coherent organization means the forms tend to hold together as bound states of information. This tendency to hold together is a direct result of the entanglement of information. Each observational event is like a screen output, and the projected images are animated over a sequence of events. This animation of images over a sequence of events always arises in the flow of energy.

How do we understand the flow of energy? Relativity theory gives the answer in terms of an observer's accelerated frame of reference [7]. Energy must be expended as an observer enters into an accelerated frame of reference, just like a rocket-ship must expend energy through the force of its thrusters as it accelerates through space.



Principle of equivalence image from mysearch.org

In relativity theory, we understand an observer's accelerated frame of reference as an accelerated world-line through space-time geometry. The holographic principle turns this understanding inside-out, since space-time geometry is a holographic projection from the observer's holographic screen to the central point of view of the observer. The observer only appears to follow an accelerated world-line through the space-time geometry that is projected from its holographic screen to the central point of view of the observer.

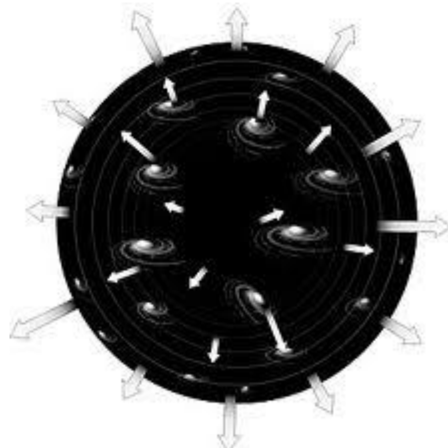


Rindler horizon image from Smolin

An observer's holographic screen is understood in the sense of an event horizon that only arises because the observer is in an accelerated frame of reference. The event horizon is a bounding surface of space that always limits the observer's observations of things in that bounded space due to the limitation of the speed of light. The event horizon demarcates a boundary in space that no light signal can cross due to the observer's accelerated frame of reference. The event horizon only arises when the observer expends energy and enters into an accelerated frame of reference.

The ultimate horizon that defines the observer's world is its cosmic horizon, which arises with the expenditure of dark energy. The cosmic horizon arises with the force of dark energy, which in relativity theory is called a cosmological constant. The force of dark energy is like a repulsive force of anti-gravity that gives rise to the exponential expansion of space. Space appears to expand away from the central point of view of the observer at an accelerated rate. The farther out in space the observer looks, the faster space appears to expand away from the observer. At the cosmic horizon, space appears to expand away from the observer at the speed of light, and so things at the cosmic horizon appear to move away from the observer at the speed of light. Since nothing can travel faster than the speed of light, the cosmic horizon is as far out in space as the observer can see things in space.

The cosmic horizon is a bounding surface of space that limits the observer's observations of things in space. Those limited observations of things in space are observed relative to the central point of view of the observer. The observer at the central point of view makes those limited observations. The bounding surface of a cosmic horizon always surrounds the observer at the central point of view. The strange aspect of the exponential expansion of space is a cosmic horizon surrounds every observer at the central point of view, which is to say the cosmic horizon is observer-dependent.

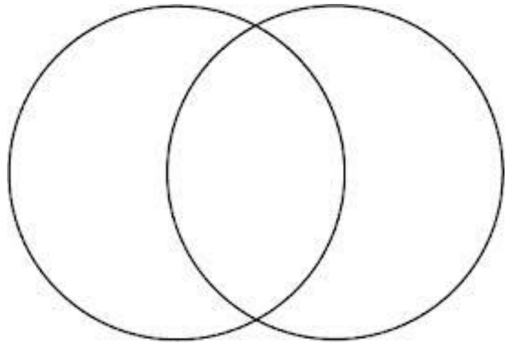


Expansion of space image from scienceblogs.com

How can space appear to expand? The answer is the curvature of space-time geometry. Space appears to contract with the attractive force of gravity, while space appears to expand with the repulsive force of dark energy. This apparent contraction or expansion of space over the course of time occurs relative to the point of view of an observer, which is the nature of the curvature of space-time geometry in relativity theory. This apparent contraction or expansion of space is just like the distortion of images that appear on a computer screen in a computer animation. This is actually a very good analogy, since the bounding surface of a cosmic horizon acts as a holographic screen that projects the images of things to the central point of view of an observer.

The natural consequence of the holographic principle and a cosmic horizon that defines the nature of an observer's world is the "one-world-per-observer paradigm". The key concept in the one-world-per-observer paradigm [2] is each observer is at the central point of view of its own holographic screen that defines everything the observer can possibly observe in its own world. That boundary constructs a quantum state for all possible observations the observer can make in its world. Each observation reduces the quantum state of the screen to an actual configuration state of information defined on the screen, and is like a screen output. Each observational event on the observer's accelerated world-line through the projected space-time geometry of its world is another screen output.

This gives a natural explanation for the one-world-per-observer paradigm, but how do we understand a consensual reality shared by many observers? The holographic principle again gives the answer. Each observer's world is defined on its own holographic screen, but those bounding surfaces of space can overlap with each other in the sense of a Venn diagram and share information [2]. Many observers can share a consensual reality together to the degree their respective holographic screens overlap and share information.



The holographic principle is a duality that relates the projected images of all the things observed in some three dimensional region of space to the way bits of information are encoded on the two dimensional bounding surface of that space [1]. Those projected images include the images of elementary particles, like the electron and photon. When the laws of physics are formulated as a 3+1 dimensional field theory, such as Einstein's field equations for the metric, Maxwell's field equation for electromagnetism, or Dirac's field equations for the electron, this formulation only applies to the three dimensional region of space half of the duality. The other half of the duality is specified by the way bits of information are encoded on the two dimensional bounding surface of that space, which is typically formulated in terms of the n eigenvalues of an nxn matrix.

The duality is a way to make a mathematical transformation from one half of the duality to the other half of the duality. Although we think it is natural to quantize field equations, such as the formulation of quantum electrodynamics, this kind of quantization only has a limited range of validity. The only quantum variables with a range of validity extending down to the Planck scale are non-commuting variables defined on a bounding surface of space [2].

What are we to make of our attempts to quantize field equations? At most, this can only give us an effective field theory [7] with a limited range of validity. These effective field theories naturally arise as a thermodynamic average in the bulk half of the duality from the non-commuting variables defined on the bounding surface of that space.

The other way to describe the duality is in terms of a holographic screen that constructs a Hilbert space of observable values for the observer's world. The Hilbert space is always constructed as a sum over all possible observable states of the observer's world, and each observation of that world is a quantum state reduction. Everything the observer can observe in its world is like a screen output that arises as this Hilbert space of observable values is reduced to some actual observable state of information defined on the screen.

The holographic principle and non-commutative geometry tell us the Hilbert space for the holographic screen is constructed in terms of an nxn matrix, which by its very nature is defined on a bounding surface of space. What then are we to make of the kind of Hilbert space that arises in a quantum field theory? Again, a QFT is only an effective field theory that arises as a thermodynamic average with a limited range of validity. In QFT, the Hilbert space is always defined in a three dimensional space that is an aspect of a 3+1 dimensional space-time geometry. Each component of the quantum field $\varphi(x, t)$ defined at some position x in that space acts like a harmonic oscillator with a spectrum of excited values [8], but this spectrum of particle excitations has a limited range of validity.

The reason no QFT can represent how space-time geometry is quantized is the covariant entropy bound [4]. The covariant bound tells us that the maximum entropy characterizing any three dimensional region of space is bounded by the n bits of information encoded on the bounding surface of that space, where n is given in terms of the surface area as $n=A/4\ell^2$. Even if a 3+1 dimensional space-time geometry is quantized, the harmonic oscillator nature of particle excitations in a QFT will overwhelm the covariant entropy bound with too many degrees of freedom (proportional to the spatial volume) once the Planck scale is approached, and so every QFT must have a limited range of validity.

What then are we to make of the field equations for the metric that describe a space-time geometry? The field equations for the metric are only an effective field theory that arises as a thermodynamic average with a limited range of validity [7]. The only valid quantum variables at the Planck scale are non-commuting variables defined on a bounding surface of space [2], which defines a Hilbert space for the holographic screen. The space-time geometry characterizing the observer's world only arises as a projection of images from the observer's holographic screen to the observer's central point of view over a sequence of screen outputs. This occurs as the observer enters into an accelerated frame of reference and appears to follow a world-line through its projected space-time geometry.

There is an easy way to see how effective field theories describing the bulk half of the duality arise from the covariant entropy bound [9]. The laws of thermodynamics specify as energy flows through a boundary, some entropy must flow along with the energy. Since entropy is defined on the boundary in terms of its surface area, the boundary must change as energy flows through it, and so the geometry of the bounded space must also change.

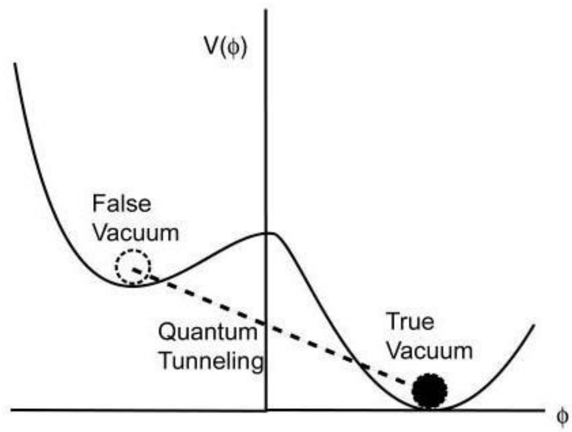
This relation between the flow of energy and entropy, the surface area of the boundary, and the geometry of the bounded space implies Einstein's field equations for the space-time metric as thermodynamic equations of state [9]. If we invoke the Kaluza-Klein mechanism [8] this generates field equations for the electromagnetic and nuclear forces. In a non-commutative geometry, not only are gauge fields generated, but also the Higgs fields [6]. With super-symmetry [1], boson and fermion fields are generated. In a nutshell, this is all of field theory, derived from nothing more than geometry, symmetry, thermodynamics, and the covariant entropy bound.

The holographic principle tells us the bounding surface of space is an event horizon that can only arise when the observer enters into an accelerated frame of reference, which requires the expenditure of energy. What is the ultimate source of this energy?

Modern cosmology [2] gives us the answer in terms of dark energy and the exponential expansion of space. Whenever dark energy is expended, space appears to expand at an accelerated rate relative to the observer's central point of view, and a surrounding cosmic horizon arises that limits the observer's observations of things in space. In relativity theory this kind of exponentially expanding space, which is characterized by a positive cosmological constant, is called de Sitter space. The cosmic horizon surrounding the observer at the central point of view is observer-dependent, as space appears to expand away from the observer faster the farther out in space the observer looks. We understand this apparent expansion of space in terms of the repulsive force of dark energy.

If we take the big bang theory seriously, we understand that at the moment of creation of the observer's world, that world is about a Planck length in size, but that world then inflates in size because of an instability in dark energy [2]. This instability in dark energy is like a process of burning that burns away the dark energy.

The expenditure of dark energy breaks the symmetry of empty space [2] by constructing an observation-limiting cosmic horizon that surrounds the observer at the central point of view. The instability in dark energy is like a process of burning that burns away the dark energy and "undoes" this broken symmetry. As the dark energy burns away to zero, the cosmic horizon inflates in size to infinity, and the symmetry is restored. We understand this "undoing" of symmetry breaking is like a phase transition from a false vacuum state to a true vacuum state. As the phase transition occurs, dark energy burns away.



Meta-stable state image from ned.ipac.caltech.edu

This burning away of dark energy explains the normal flow of energy in the observer's world in the sense of the second law of thermodynamics. This is easiest to understand in terms of a cosmological constant Λ. Relativity theory tells us the radius of the observer's cosmic horizon, R, is related to the cosmological constant as $R^2/\ell^2=3/\Lambda$. The holographic principle [4] tells us the absolute temperature of the cosmic horizon is related to its radius as $kT=\hbar c/2\pi R$. At the moment of creation, R is about equal to ℓ, Λ is about equal to 1, and the absolute temperature is about equal to 10^{32} degrees Kelvin. As dark energy burns away, Λ decreases in value, R inflates in size, and the temperature cools. As Λ decreases to zero, R inflates to infinity, and the temperature cools to absolute zero.

There is something odd about this phase transition from a false vacuum state to a true vacuum state, as dark energy burns away and the cosmological constant decreases in value from its initial high value to its final value of zero. This phase transition is the nature of the event that the observer at the central point of view of a cosmic horizon perceives as a big bang event [2]. The odd nature of this scenario is that the total transition to zero can occur over a series of many phase transitions. Each phase transition will appear to the observer as another big bang event. Each phase transition can burn away part of the total amount of dark energy, and is like a transition from a false vacuum state to a less false vacuum state characterized by a lower value of the cosmological constant. With each phase transition, the observer's cosmic horizon inflates in size.

Each inflation of the observer's world will appear to the observer as another big bang event. In the exponential expansion of space scenario, the repulsive force of dark energy always counteracts the attractive force of gravity, and so there is only the expansion of space and no contraction. Unlike the cyclical idea of a big crunch followed by a big bang, there is only the expansion of space and repetitive inflations of the cosmic horizon.

In this scenario, a big bang event is only an inflation in size of the observer's cosmic horizon. Each phase transition resets the radius of the cosmic horizon at the beginning of each big bang event, and the amount of dark energy that burns away during the phase transition resets the radius of the cosmic horizon at the end of the big bang event. A series of such inflations, each occurring as a phase transition, ultimately must terminate when the cosmological constant approaches its final value of zero, the radius of the cosmic horizon approaches infinity, and the true vacuum state is finally reached.

This understanding is not only consistent with our understanding of the big bang event, but also with the current measured value of the cosmological constant, based on the rate at which distant galaxies are observed to accelerate away from us. The current measured value of Λ is about 10^{-123}, which corresponds to the size of the observable universe of about 15 billion light years [1].

The second law of thermodynamics simply says that heat tends to flow from a hotter object to a colder object because the hotter object radiates away more heat, which is thermal radiation. The instability in dark energy explains the second law as dark energy burns away, the observer’s world inflates in size and cools in temperature, and heat tends to flow from hotter states of the observer’s world to colder states of the observer’s world.

Second law of thermodynamics image from Penrose

The normal flow of energy through the observer’s world simply reflects this normal flow of heat as the dark energy burns away and the observer’s world inflates in size and cools. This normal flow of energy naturally arises in a thermal gradient. One of the mysteries of the second law is understanding time's arrow, or how the normal course of time is related to this normal flow of energy. The burning away of dark energy explains this mystery. As far as the holographic principle goes, a thermal gradient is also a temporal gradient. The holographic principle reduces concepts of temperature, the normal flow of energy and the course of time to geometry, and so these concepts are intrinsically related to each other.

To say the course of time arises in a temporal gradient is the same as to say the flow of energy arises in a thermal gradient. This is what the holographic principle, the burning away of dark energy and the second law of thermodynamics tell us. As dark energy burns away, the observer's cosmic horizon inflates in size and cools in temperature, which drives the normal flow of energy and course of time in the observer's world. This is like the flow of a river down a mountainside under the influence of gravity, except the force of dark energy is repulsive, and is like a kind of anti-gravity. The gradient is established as dark energy burns away, which is like a decrease in the repulsive force of anti-gravity.

What are we to make of the expenditure of other forms of energy besides dark energy? Modern cosmology and physics [1] give the answer in terms of symmetry breaking. All forms of positive energy arise from dark energy through a process of symmetry breaking.

A key aspect of symmetry breaking [2] is not usually discussed. The nature of symmetry breaking that allows for the emergence of a world along the lines of the inflationary scenario is only possible if the total energy of that world adds up to zero. The remarkable discovery of modern cosmology is cosmic observations indicate the total energy of the observable universe is exactly zero. This is possible in relativity theory since the negative potential energy of gravitational attraction can exactly cancel out the total amount of dark energy and any other forms of positive energy that arise from dark energy [10].

How do other forms of energy, like mass energy, arise from dark energy? The answer is symmetry breaking. As dark energy burns away, high energy photons are created, and these photons can create particle-antiparticle pairs, like proton-antiproton pairs. One of the mysteries of cosmology is why there are so many protons in the universe and so few antiprotons. Symmetry breaking gives the answer [2]. At high energies, antiprotons can decay into electrons and protons into positrons, but there is a difference in the decay rates due to a broken symmetry, and so more antiprotons decay than protons. As the universe cools, the protons become stable, and so that is what is left over. Even the mass of the proton arises through a process of symmetry breaking that we call the Higgs mechanism. The expenditure of energy that characterizes the fundamental gauge forces, like electromagnetic energy in a living organism, or nuclear energy in a star, all arises from dark energy through a process of symmetry breaking, but all of this positive energy is exactly cancelled out by the negative potential energy of gravitational attraction.

The fact that the total energy of the observable universe exactly adds up to zero tells us something important. Since everything in the world is composed of energy and all energy ultimately adds up to zero, this tells us that everything is ultimately nothing.

A common problem in both the physical and biological sciences is spontaneous emergence. This problem of spontaneous emergence always reduces down to some coherently organized form of information that spontaneously develops and is organized with the ability to self-replicate its form over a sequence of events. Whether we speak about a self-replicating living organism or a physical form of organization, like a star, planet, solar system or galaxy, we're still speaking about a coherently organized form of information with the ability to self-replicate its form.

Self-replication of form always occurs over a sequence of events in the course of time that arises in the flow of energy. There is no possible way to discus the course of time without discussing the flow of energy. Whatever form we consider, like a life-form, that self-replicating form is animated over a sequence of events in the flow of energy, like the forms of information or projected images we observe on a computer screen over a sequence of screen outputs that arise in the flow of energy that energizes the computer.

For self-replication of form to occur, not only is the form of information coherently organized, but the flow of energy through the form that animates the form is also coherently organized. The problem of spontaneous emergence boils down to the problem of how bits of information are coherently organized within the form and how energy coherently flows through the form to allow for self-replication of form. By its nature, such coherent organization defines a bound state of information and energy.

How does the coherent organization that underlies the spontaneous emergence of all the coherently organized forms of information we observe in the world develop? We might say coherent organization is inherent in the laws of physics, but this begs the question: where do the laws of physics that govern a world come from?

The answer is everything in the world, every aspect of that world, spontaneously emerges due to the development of coherent organization. Even the laws of physics that govern a world spontaneously emerge as that world emerges. Even an entire world is coherently organized. Of course, this is precisely what the holographic principle tells us about the nature of an observer and its world, since that world is coherently defined on a holographic screen.

The problem we have is to understand spontaneous emergence in its most general form, with enough generality that it can explain how an entire world and the laws of physics that govern that world can spontaneously emerge.

The solution to this problem of spontaneous emergence, as it applies not only to the emergence of forms but also to the emergence of a world and the laws of physics that govern that world, is the concept of symmetry. Everything that can spontaneously emerge in a world, even the laws of physics that govern that world, even the emergence of that world itself, is an example of spontaneous symmetry breaking. We understand symmetry breaking in the sense of a phase transition, like the spontaneous magnetization of a magnet, or the freezing of liquid water into ice or the melting of ice back into water.

A key concept in all examples of symmetry breaking is the idea of temperature, which is a measure of the random thermal or kinetic energy of the microscopic elements of any macroscopic object, like water molecules inside a piece of ice. Another example are the atoms, electrons, and atomic nuclei inside a magnet that carry spin or orbital angular momentum and have an intrinsic magnetic field due their electric charges and angular momenta. The macroscopic magnet develops a macroscopic magnetic field when the microscopic magnetic fields of the microscopic elementary constituents align together, just as liquid water freezes into solid ice when the water molecules bind together.

This binding or aligning of the microscopic elementary constituents occurs as a phase transition when the temperature reaches a critical level and the force of attraction between the elementary constituents becomes greater than their kinetic tendency to randomly move around. The other way to say this is their potential energy of attraction becomes greater than their kinetic energy of random movement. Coherent organization spontaneously develops due to this tendency of the elementary microscopic constituents to bind or align together when the temperature becomes low enough, and the balance between potential and kinetic energy is tipped in favor of attractive potential energy.

The reason spontaneous emergence can apply to the emergence of an entire world is because that world is always defined on a holographic screen in terms of the bits of information encoded on the screen. These bits of information are like spin variables that carry random kinetic or thermal energy, and so they have a tendency to flip back and forth between the "up" or "down" positions, but they also have a tendency to align together. The n bits of information defined on the holographic screen are defined by the n eigenvalues of an nxn matrix, but since these n eigenvalues are all entangled together, they have a tendency to align together. A nice example of this phenomena is alignment in a spin network [10]. Coherently organized forms of information can therefore develop on the holographic screen through the same kind of symmetry breaking mechanism that describes how a magnet becomes spontaneously magnetized. The temperature of the holographic screen only represents the average thermal energy of each bit of information encoded on the screen. As heat flows in a thermal gradient and the temperature is lowered, the bits of information have a natural tendency to align together.

Symmetry breaking thus explains how coherently organized forms of information spontaneously emerge in a world defined on a holographic screen. The question is: where does this symmetry come from in the first place?

The answer is symmetry is a characteristic of the expenditure of energy that creates an entire world in the first place. We understand this original expenditure of energy as dark energy and the exponential expansion of space. The energy expended as space expands gives rise to all the symmetries that underlie all the various kinds of symmetry breaking. The most fundamental kind of symmetry breaking is the creation of a cosmic horizon that surrounds an observer at the central point of view. Since the observer's cosmic horizon acts as a holographic screen, the observer's world is defined by this act of symmetry breaking. The original symmetries broken in that world are symmetries of space that arise with the expenditure of dark energy and the exponential expansion of space [2].

Not only does the observer's world spontaneously emerge as dark energy is expended, but the laws of physics that govern that world also emerge as that world emerges. The laws of physics are constrained by the nature of symmetry, but they can only take on their specific forms through a process of symmetry breaking [1]. All the parameters that characterize the laws of physics that govern a world, such as particle masses and coupling constants, arise through a process of symmetry breaking. The general form of the laws of physics, such as laws of gravity and electromagnetism, are constrained by the symmetries of space that arise with the expenditure of dark energy and the exponential expansion of space, but the parameters within these laws take on their specific values through a process of symmetry breaking. Like a phase transition that freezes water into ice or freezes the direction of the magnetic field of a magnet into a specific direction, these specific values are "frozen" into place once the phase transition is finished.

There is an important aspect of symmetry breaking that is usually not discussed. Whatever symmetry is broken, that symmetry can be broken in many different ways. For example, with the spontaneous magnetization of a magnetic, the magnet's macroscopic magnetic field can point in many different directions. In much the same way, the parameters that characterize the laws of physics, the particle masses and the coupling constants, can take on many different values [1].

How are the values of these parameters in the laws of physics that govern a world chosen? Who chooses them? Who chooses the original symmetries of space that are inherent in a world and that are broken as that world emerges?

This problem of choosing how the symmetries of space are broken as a world emerges, not to mention the problem of how all the symmetries of space emerge in the first place, is not a problem that physicists want to address, and so they assume a process of random choice, but then are left with the difficult problem of explaining how all the parameters in the laws of physics become fine-tuned enough to allow life-forms to develop. As is well known [1], if the charge of the electron changes by a few percent, or if certain nuclear decay rates change by a few percent, the universe would not be a hospitable place for life-forms to develop, but this is the inevitable result of a random process of choice. To get around this problem, physicists [2] have had to resort to such absurdities as multiple universes. If there are an infinite number of universes, then random choice will allow the parameters in the laws of physics to become fine-tuned enough in some of them to allow life-forms to develop. Unfortunately, an infinite number of universes results in the absurdity of the measure problem [2], where both anything and nothing can be explained.

There is a natural way to explain how all the parameters in the laws of physics that govern the world are chosen in a fine-tuned enough way that allows for the development of life-forms. The solution is biased choice. Biased choice is the natural consequence of the holographic principle and the one-world-per-observer paradigm.

Every observer's world is defined on a holographic screen that surrounds the observer at the central point of view. We understand the observer as a focal point of consciousness that arises in relation to the screen and to which the images of all distinct things in that world, all the coherently organized forms of information that are defined on the screen, are projected over a sequence of screen outputs.

Since the observer is a focal point of consciousness that arises in relation to a holographic screen defining everything in its world, it is natural the observer can focus its attention on different things in that world. This ability to shift the focus of its attention onto different things in its world naturally explains how the observer expresses its inherent bias as it chooses to observe different things in its world.

In this sense, everything in the observer's world spontaneously emerges as the observer expresses its natural bias by shifting the focus of its attention onto different things in its world. The observer is naturally biased to feel connected to its world, and feelings of connection naturally arise as the flow of energy through all the things in its world come into alignment. These feelings of connection are the nature of the coherently organized flow of energy through the various things in that world that allows for self-replication of form, animates those things, and relates one thing to another thing. In the sense of the expression of emotions that animate the form of a body, the observer is naturally biased to feel connected to things in its world as the desires of that body become satisfied.

This inherent bias of the observer to feel connected to its world explains how coherent organization develops and how everything in the observer's world spontaneously emerges. It even explains how the observer's world emerges in the first place, and how the laws of physics that govern that world emerge. The observer's world and the laws of physics emerge in such a way as to make the expression of life in that world possible, so that the expressed desires of those life-forms can become satisfied.

What about the consensual reality shared by many observers? Many different observers can share a consensual reality to the extent their holographic screens overlap and share information. To a limited degree, each observer makes biased choices in its own world as it focuses its attention on that world, but the biased choices of all the different observers that share the consensual reality together give rise to all the coherently organized forms of information that develop in that consensual reality. Even the laws of physics that govern that consensual reality are chosen in a collective way. In other words, that shared consensual reality is the reality that all the different observers have chosen together.

The holographic principle and the one-world-per-observer paradigm tell us that as an observer expends energy and follows an accelerated world-line through the space-time geometry projected from its own holographic screen, the observer makes observations of things in that bounded space. Each observation of things by the observer is like a screen output from the observer’s screen to the observer's central point of view. With any screen output, the observable images of things are projected from the screen to the observer’s central point of view, and those projected images are animated over a sequence of events. Each event on the observer’s world-line is another screen output. These events arise in the flow of energy that characterizes the observer’s accelerated frame of reference.

To be clear about things, energy and information are the same thing. Information is what energy looks like when observed at an instant of time. Each coherently organized form of information is composed of bits of information, and those forms of information are animated over a sequence of events. Energy is what a form of information looks like when that form is animated in the course of time. Information is a static concept while energy is a dynamic concept.

The equivalence of energy and information has a deep connection in quantum theory and in the way quantum theory is unified with relativity theory. When we speak of bits of information encoded on a holographic screen, we’re speaking about the quantized bits of information that define everything in an observer’s world [1]. The observer’s holographic screen is characterized by a quantum state of potentiality describing all possible ways bits of information can become encoded on the screen. This quantum state of potentiality defines everything the observer can possibly observe in its world. We can think of this quantum state of potentiality as a sum over all possible configuration states of information, where a configuration state specifies a specific configuration in the way bits of information are encoded on the screen. A screen output must chose a specific configuration state from the quantum state when the observation of anything is observed. In quantum theory, this observational choice is called a quantum state reduction.

Quantum theory tells us that the observation of any observable thing by an observer implies an observer-observation-observable relationship, while each observation implies a choice as the quantum state of potentiality is reduced to an actual configuration state of information. In this sense, each screen output is a choice.

There is something very odd about quantum theory that is usually not discussed. Every quantum state reduction is a choice, which occurs at a decision point on the observer's world-line. At every decision point, the observer has a choice to make about what to observe in its world and which path to follow. Physicists have arbitrarily assumed that all choices are made randomly, in an unbiased way, but this assumption is only made since physicists want the laws of physics to have predictability. If choices are made in a biased way, then the laws of physics lose their predictability, and all bets are off, so to speak.