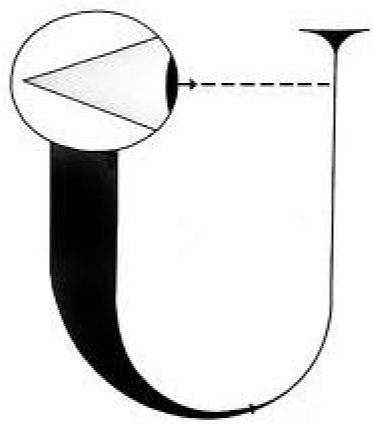
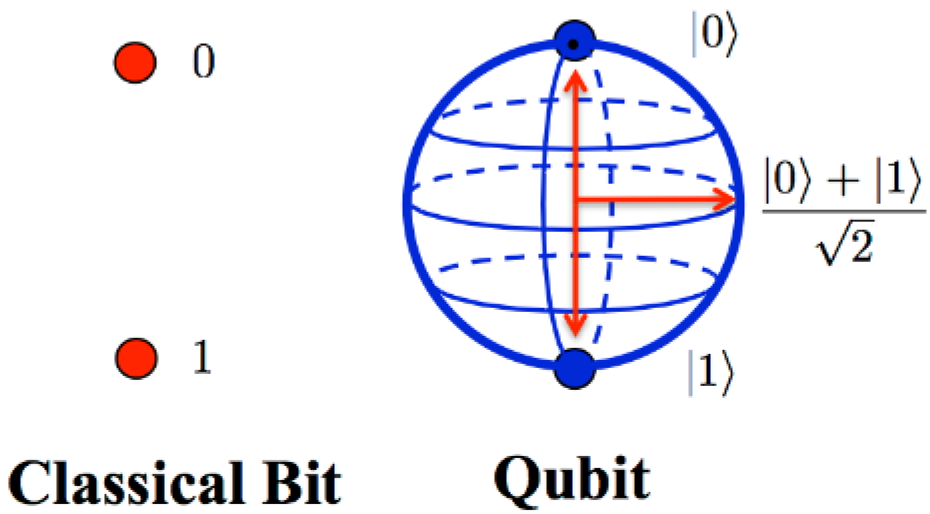
Physics Is About Our Information for the World and Is Not About the World Because There Really Is No World

In recent years, there's been an explosion of interest in the concept of entropic information as the foundation for quantum theory, following the pioneering work of Aton Zeilinger. It turns out that the whole mathematical structure of quantum theory can be deduced from the concept of entropic information. This is a natural extension of the idea of John Wheeler that everything we perceive in the world can be reduced to bits of information, which Wheeler called "It from bit". This idea tells us that everything we perceive is like an image displayed on a computer screen that can be reduced to bits of information encoded on the screen. Wheeler's idea is inherently an observer-centric description of the world. An observer must perceive the forms of information that are projected like images from the screen to the observer's point of view.



Universal Observer

What exactly is entropic information? The basic concept is a quantized bit of information, which is called a qubit. A qubit is mathematically represented by an SU(2) matrix, like a Pauli spin matrix, which encodes information in a binary code. The Pauli spin matrix represents a spin ½ variable that can only be observed to point up or down, and so encodes information in a binary code of 1's and 0's like a switch that is either on or off. Unlike a classical switch, this quantized information is entangled. Quantum entanglement basically means that the information is encoded in a rotationally invariant way. This is mathematically represented by the SU(2) matrix, which gives a mathematical representation of rotational symmetry on the surface of a sphere. Quantum entanglement is a direct result of the rotationally invariant way qubits of information are encoded on the surface of a sphere, as mathematically represented by matrices.



Qubit of Information Encoded on the Surface of a Sphere

The big question about the nature of entropic information as the foundation of quantum theory is: Where exactly is this information encoded? The nature of entropic information, which is a qubit, fundamentally answers this question. A qubit is mathematically represented by a matrix, which is a two dimensional array of numbers. That information must be encoded on a two dimensional surface. An SU(2) matrix encodes information in a binary code, but also gives a mathematical representation of rotational symmetry on the two dimensional surface of a sphere. A qubit of information, as mathematically represented by a two dimensional array of numbers called a matrix, can only encode information on a two dimensional surface.

Where does this two dimensional surface come from? Around the same time that entropic information as the foundation of quantum theory was proposed, the holographic principle of quantum gravity was also discovered. The holographic principle fundamentally explains where the two dimensional surface, which encodes qubits of information in the form of a two dimensional array of numbers called a matrix, comes from. That two dimensional surface is called an event horizon, which always arises in an observer's accelerated frame of reference.

The most fundamental science we have is theoretical physics. Theoretical physics is the science that explains the nature of the space-time geometry of the world and the nature of all matter and energy in the world. In the last 25 years or so, theoretical physics has come to the conclusion that neither the space-time geometry of the world nor the nature of matter and energy in the world are really fundamental. Instead, the fundamental things are information and energy that give rise to the appearance of the space-time geometry of the world and the appearance of all matter and energy in the world. Everything that appears in the world, including the space-time geometry of the world and the nature of all matter and energy in the world, is reducible to more fundamental information and energy. This conclusion is called the holographic principle of quantum gravity.

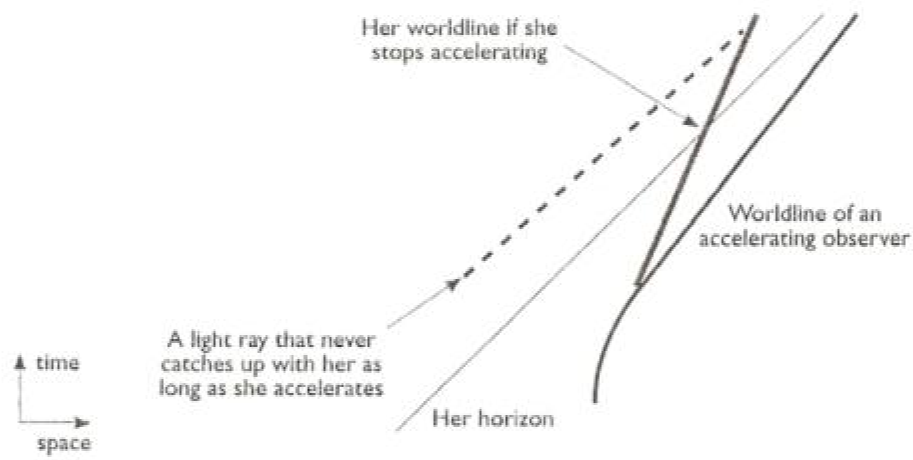
The holographic principle scientifically explains how all the fundamental information for the world is encoded and how all the fundamental energy for the world is expressed.

The holographic principle was first suggested by Leonard Susskind and Gerard 't Hooft to resolve paradoxes that seemed to arise in a theory of quantum gravity if quantum gravity was understood to be formulated in the conventional sense of a quantum field theory, like quantum electrodynamics. The holographic principle is the only known way to resolve these paradoxes. Shortly after being suggested, a mathematically exact demonstration of the holographic principle was discovered by Juan Maldacena in the form of the AdS/CFT correspondence.

The problem with trying to understand quantum gravity along the lines of a quantum field theory like quantum electrodynamics is that all quantum field theories inherently describe the behavior of point particles, like the electron and the photon, within some fixed background space-time geometry, which is usually taken to be flat Minkowski space. The point particles are assumed to exist within and to propagate through that fixed background space-time geometry. A point particle is assumed to be located at some space-time point in that fixed space-time geometry and to move along some path through that fixed space-time geometry. This is a problem because the nature of gravity, as formulated by Einstein's field equations for the space-time metric, is all about the dynamical curvature of a space-time geometry. It's a logical contradiction to assume that the graviton is a point particle that exists within and propagates through some fixed background space-time geometry, like flat Minkpowski space, when the graviton is also assumed to give a mathematical representation of the dynamical curvature of that space-time geometry.

A problem arises when we try to understand the force of gravity as due to the exchange of a quantum particle called the graviton between other massive particles the same way we're able to understand the electromagnetic force as due to the exchange of the quantum particle called the photon between electrically charged particles. The exchange of a quantum particle between other particles like electrons implies there is a space-time geometry within which that particle can propagate. In order to formulate the quantum field theory of electromagnetism in this way, we have to assume there is a background space-time geometry of flat Minkowski space within which the photon can propagate. A problem arises when we try to understand the graviton in the same way. The graviton is supposed to give a representation of the curvature of space-time geometry, but to understand the graviton as the quantum particle of the gravitational field, we have to assume that the graviton propagates through flat Minkowski space, since that is the only way we can formulate quantum field theory. There is something logically inconsistent with assuming that the graviton propagates through flat Minkowski space while it also gives a representation of the dynamical curvature of space-time geometry, which is the nature of the gravitational force.

It simply is a logical contradiction to assume that a theory of quantum gravity can be understood in terms of a quantum field theory that describes the behavior of a point particle called the graviton if the graviton is assumed to be a point particle that exists within and propagates through some fixed background space-time geometry, like flat Minkpowski space, when the graviton is also assumed to give a mathematical representation of the dynamical curvature of that space-time geometry. This logical contradiction is the fundamental reason the idea of quantum gravity as a quantum field theory was abandoned in favor of the holographic principle. The holographic principle most definitely does not describe the physical world in terms of a quantum field theory. The holographic principle fundamentally explains how a holographic world is created when a two dimensional surface of space encodes qubits of information in the form of a two dimensional array of numbers called a matrix. That two dimensional surface of space is called an event horizon, which always arises in an observer's accelerated frame of reference.

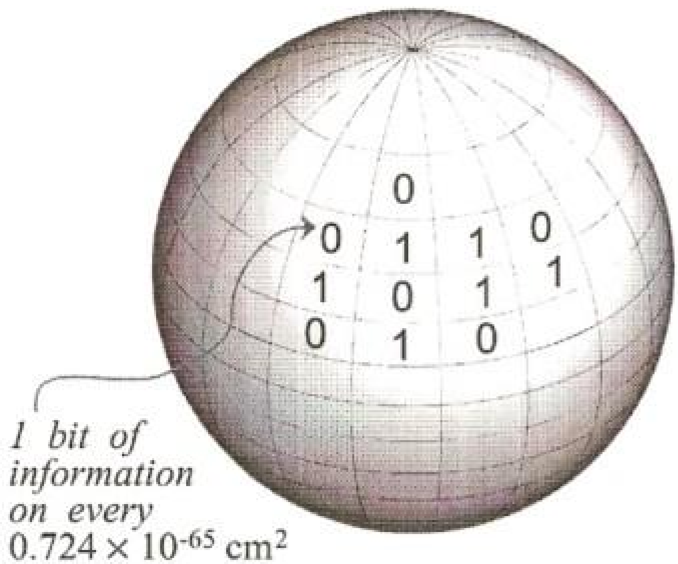


Accelerating Observer's Event Horizon

The observations of an accelerating observer in three dimensional space are always limited by the two dimensional surface of an event horizon. The observer's event horizon is as far out in three dimensional space as the observer can observe things in space. Nothing is observable to the observer beyond the limits of its event horizon. This limitation of the observer's observations is understood in relativity theory to be a direct consequence of the constancy or limitation of the speed of light, which is like the maximal rate of information transfer in a computer network. Nothing is observable to the observer beyond the limits of its event horizon because no light signal that originates on the other side of its event horizon can ever cross the horizon and reach the observer as long as the observer continues to undergo accelerated motion.

Every accelerating observer will have its observations of things in three dimensional space limited by the two dimensional surface of its event horizon. The observer's event horizon is the two dimensional surface of space that encodes qubits of information in terms of matrices, which are two dimensional arrays of numbers. When the observer's event horizon encodes qubits of information in this way, the observer's event horizon turns into its holographic screen.

The holographic principle was discovered when the observer's event horizon was understood to encode information for everything the observer can perceive in its own holographic world. That encoding of information occurs on the observer's event horizon that acts as a holographic screen, similar to how information is encoded on a computer screen. The screen encodes information in terms of pixels, where a pixel is an area element defined on the screen. Each pixel encodes a single bit of information in a binary code of 1's and 0's. The observer's event horizon, which is a two dimensional bounding surface of space, is encoding information just like a computer screen.



Holographic Principle

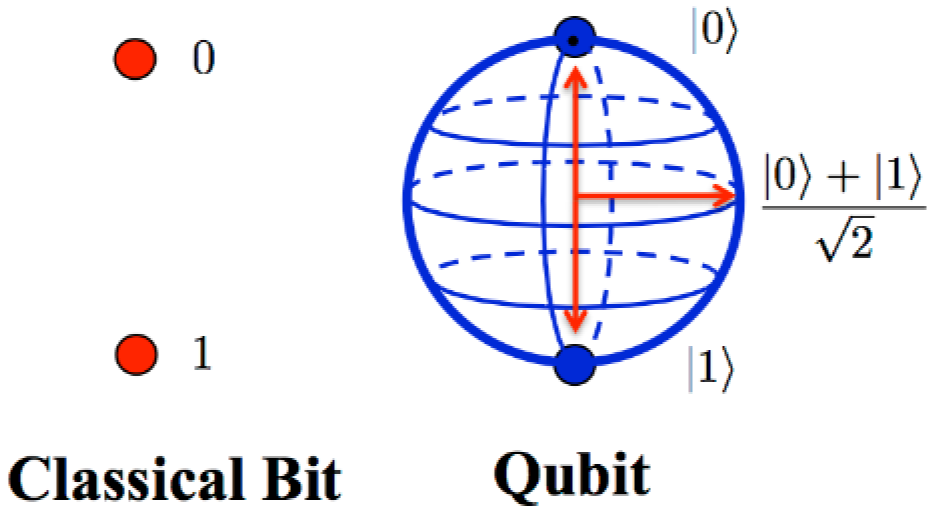
The holographic principle is telling us that the whole thing has to begin with an observer in an accelerated frame of reference. In relativity theory, the observer is nothing more than the perceiving consciousness present at a point of view in space. Relativity theory doesn't attempt to explain what consciousness is, only that the observer is present at a point of view in space. It is this point of view in space that follows a world-line. When that point of view in space undergoes accelerated motion, an event horizon arises that limits the observer's observations of things in space. That limitation of the observer's observations in space is due to the constancy of the speed of light for all observers, independent of their state of relative motion. The speed of light gives the maximal rate of information transfer in three dimensional space. The observer's event horizon is a two dimensional bounding surface of space that limits its observations of things in space. Nothing is observable to the observer beyond the limits of its event horizon.

The observer's event horizon, which is a two dimensional bounding surface of space, turns into its holographic screen when its horizon encodes qubits of information, which are mathematically represented by two dimensional arrays of numbers called matrices. This is just like what an observer can observe on a computer screen. Everything observable is reducible to qubits of information encoded on the screen. Each pixel on the screen encodes a qubit of information. In quantum gravity, the pixel size is given in terms of the Planck area, which is specified in terms of the gravitational constant, the speed of light and Planck's constant as $\ell^2=\hbar G/c^3$.

$$\ell_p = \sqrt{\frac{\hbar G}{c^3}} \sim 1.6 \times 10^{-35}\mathrm{m}$$

Planck Length

The holographic principle tells us the Planck length is the smallest possible distance scale that we can measure since a Planck-size event horizon, which encodes a single qubit of information, is the smallest possible event horizon. A single qubit of information can only be encoded on a Planck-size event horizon. A qubit is the smallest amount of information we can ever measure, and so the Planck length is the smallest possible distance scale we can ever measure.



Qubit of Information Encoded on the Surface of a Planck-size Event Horizon

The classic example of the Planck length as the ultimate distance scale is a black hole. A black hole is a region of space where the force of gravity is so strong that even light cannot escape. That region of space is defined by a bounding surface of space called an event horizon. At the surface of the event horizon, the velocity of escape from the black hole, called escape velocity, is equal to the speed of light. Since nothing can travel faster than the speed of light in relativity theory, nothing can escape from a black hole, not even light.

The event horizon of a black hole is a special spherical surface where the velocity of escape from that surface is the speed of light. Einstein's theory of relativity determines the radius of the event horizon in terms of the mass of the black hole, which is called the Schwarzschild radius.

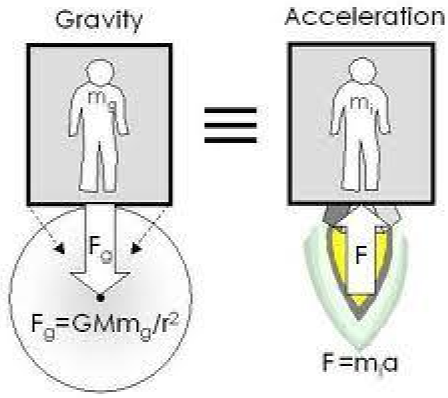
$$R = \frac{2GM}{c^2}$$

Schwarzschild Radius of the Event Horizon of a Black Hole

The event horizon of a black hole is always defined in an observer's frame of reference, which is a coordinate system with an observer at the origin or central point of view of that coordinate system. An observer always measures its own space-time geometry in that coordinate system. The observer measures distances in space and intervals in time between events that take place in its own frame of reference or coordinate system that defines its own space-time geometry. The space-time metric is a way of mathematically representing those measurements of distances in space and intervals in time. At the event horizon of a black hole, those measurements break down. Nothing can be measured by the observer beyond the event horizon of the black hole. The observer's own space-time geometry breaks down at the event horizon of the black hole. The observer can measure nothing beyond the event horizon, which is to say the event horizon is a bounding surface of space that limits the observer's observations of things in space. That limitation arises from the finite nature of the speed of light, which gives the maximal rate of information transfer in three dimensional space. That limitation also arises because the speed of light is the same for all observers, independent of their relative states of motion.

We normally think that the event horizon of a black hole is created by the force of gravity that arises from the mass of the black hole, but that is not quite correct. The event horizon of a black hole is an observer-dependent observation. The effects of the event horizon of a black hole only appear to an accelerating observer when the observer is in an accelerated frame of reference. It is only an accelerating observer in an accelerated frame of reference that observes the effects of the event horizon of the black hole. An observer in a freely falling frame of reference observes no effects of the event horizon. As far as the freely falling observer is concerned, there is no event horizon. Only the accelerating observer observes the effects of the event horizon.

In relativity theory, this distinction between the different effects that different observers observe in different frames of reference is called the principle of equivalence. This principle says there is no way to distinguish the effects of a force from the effects of an acceleration. The exertion of a force is always equivalent to an acceleration. Any force, like the force of gravity, is equivalent to an observer's acceleration, like an observer in a rocket-ship that accelerates through space. This equivalence specifically applies to the effects observed by an accelerating observer. An accelerating observer observes the same effects as those caused by the exertion of a force. In no significant way can the force of gravity be distinguished from an observer's acceleration. An accelerating observer observes the same effects of gravity as caused by the exertion of a force.



Principle of Equivalence

In terms of the event horizon of a black hole, the effects of the event horizon are only observed by an accelerating observer that remains in a stationary position outside the event horizon of the black hole. An observer that hovers in a stationary position just outside the event horizon of a black hole must accelerate away from the black hole with an equal but opposite acceleration as that caused by the force of gravity that pulls the observer into the black hole. It is as though the observer is in a rocket-ship that accelerates away from the black hole in order to maintain its stationary position. This acceleration defines the observer's accelerated frame of reference. Only the accelerating observer observes the effects of the event horizon of the black hole. A freely falling observer that falls into the black hole observes no effects of an event horizon.

The effects of the event horizon of a black hole are solely observer-dependent effects that arise in the observer's accelerated frame of reference. Only the accelerating observer observes them. This is odd, since at the event horizon of the black hole, the observer's space-time geometry appears to break down. For example, the effect of time dilation appears to become infinite at the event horizon as observed by the accelerating observer. From the accelerating observer's own point of view, as things appear to fall into the black hole, it appears to take an infinite amount of time for those things to approach the event horizon, and they never really cross the horizon. From the accelerating observer's own point of view, nothing ever actually crosses the event horizon as things appear to fall into the black hole. As observed by the accelerating observer, everything that falls into the black hole seems to get stuck at the event horizon since it takes an infinite amount of time for things to approach the event horizon. For the freely falling observer, there is no effect of time dilation since there is no event horizon. The things that fall into the black hole with the freely falling observer just fall into the black hole unimpeded by an event horizon.

This breakdown of an accelerating observer's space-time geometry at the event horizon of a black hole has profound consequences when we try to quantize the gravitational field the same way we quantize any other quantum field theory. Just as the effect of time dilation at the event horizon tells us that time intervals between events become infinite at the event horizon as observed by the accelerating observer, the problem has to do with the measurement of distances. The bottom line is that there is a smallest possible distance scale that can be measured. This smallest possible distance scale is called the Planck length. The basic problem is that in quantum theory, the way we measure any distance scale is by scattering a quantum particle, like a photon of light, off of whatever object we are trying to measure. If we want to accurately measure the size of that object, we have to use an appropriate amount of energy inherent in the photon of light. The energy of the photon is given in terms of its frequency as $E=hf$. This relation between energy and frequency is what defines the photon as a quantum particle or as an excitation of the electromagnetic field. The photon's frequency is related to its wavelength in terms of the speed of light as $f=c/\lambda$, and so the photon's energy is given in terms of its wavelength as $E=hc/\lambda$.

The way we measure the size of an object is by matching the photon's wavelength to the object's distance scale. This means we have to use higher energy photons to measure smaller objects. For example, we can visualize a biological cell with an ordinary light microscope, but if we want to visualize a virus, we need to use an electron microscope. The wavelength of light generated by an electron microscope is in the range of x-rays, which is much smaller than the wavelength of visible light. Correspondingly, an x-ray photon carries much more energy than a visible light photon. The smaller the object we want to measure, the higher the energy and the smaller the wavelength of the photon we need to use to make that measurement.

The problem is that when we combine quantum theory with gravity, we discover that there is a smallest possible distance scale that we can measure. Since energy is equivalent to mass as $E=Mc^2$, if we concentrate enough energy into a small enough distance scale or region of space, we create a black hole. Einstein's theory of relativity tells us that this distance scale is defined by the radius of an event horizon given in terms of the mass of the black hole as $R=2GM/c^2$. If this distance scale is set equal to the wavelength of a photon of energy $E=hc/\lambda$, and E is given in terms of the mass M of a black hole as $E=Mc^2$, then $R=2GM/c^2=2GE/c^4=2hG/\lambda c^3$. If we set these distance scales approximately equal as $R=\ell=\lambda$, then the distance scale ℓ at which a black hole must form is approximately given as $\ell=2hG/\ell c^3$. The Planck length is defined by $\ell^2=\hbar G/c^3$.

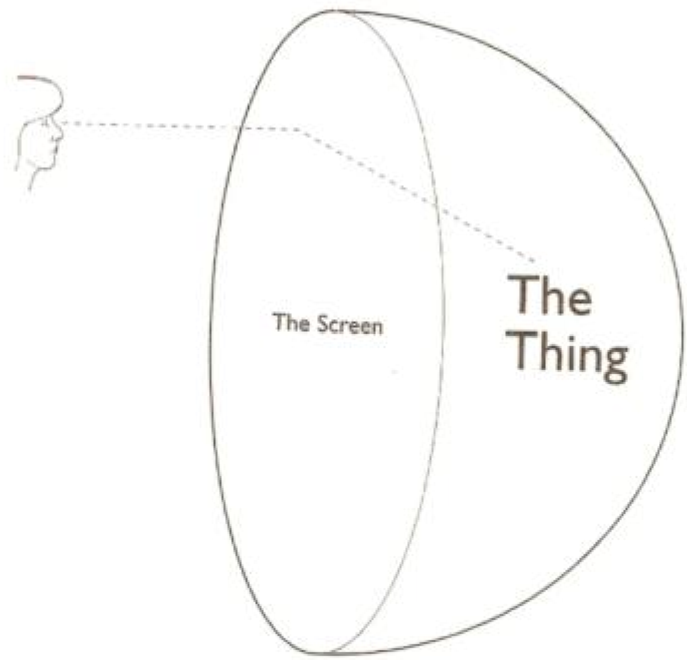
The Planck length is the smallest possible distance scale that can be measured. If we try to measure smaller distance scales, we concentrate so much energy into such a small region of space that we create a black hole. If we concentrate even more energy into an even smaller region of space, we only make the black hole bigger. A bigger, more massive black hole has a larger event horizon. The event horizon of a black hole is a limitation on our ability to measure things in space since nothing is observable beyond the limits of an event horizon as observed by an accelerating stationary observer outside the event horizon. In effect, just like infinite time dilation at the event horizon, the event horizon is a breakdown in the accelerating observer's ability to measure distances in its own space-time geometry. This breakdown in the accelerating observer's ability to measure its own space-time geometry beyond the limits of the event horizon is reflected in a smallest possible measurable distance scale. The Planck length as the smallest possible distance scale that can be measured by an accelerating observer signifies this breakdown in the observer's measurement of its own space-time geometry.

The logical inconsistency of all attempts to understand the gravitational field as a quantum field theory or to unify gravity with the other fundamental forces understood in terms of quantum field theory reflects this breakdown in an accelerating observer's ability to measure its space-time geometry beyond the limits of an event horizon or to measure distance scales smaller than the Planck length. Due to this intrinsic limitation imposed on an accelerating observer by the effects of gravity in terms of measuring its own space-time geometry, it is not possible to understand the gravitational field as a quantum field theory. This means all attempts to unify gravity with the other fundamental forces understood in terms of quantum field theory are doomed to failure. The problem boils down to the very nature of space-time geometry. Quantum field theories are not consistent with gravity because they're not consistent with the dynamical curvature of space-time geometry. Quantum field theories can only be defined in gravity-free flat Minkowski space. On the other hand, the curvature of space-time geometry is not consistent with quantum field theory. Putting gravity and quantum theory together implies the breakdown of space-time geometry as reflected by the Planck length, which is the smallest possible measurable distance scale.

The way the holographic principle resolves this problem is through the encoding of entropic information on the surface of an event horizon. The fundamental nature of entropic information is a qubit, which is mathematically represented by a two dimensional array of numbers called a matrix. Qubits of information are encoded on the two dimensional surface of an observer's event horizon, which always arises in the observer's accelerated frame of reference. The smallest possible event horizon is a Planck-size event horizon that encodes a single qubit of information and explains why the Planck length is the smallest possible measurable distance scale, since the smallest amount of information that can ever be measured is a single qubit. A larger event horizon encodes more qubits of information. It is as though the event horizon is covered by pixels and each pixel encodes a qubit of information, where the pixel size is the Planck area.

The holographic principle is weird. The observer's event horizon turns into its holographic screen when it encodes qubits of information. Everything the observer observes in its own holographic world can be reduced to qubits of information encoded on its own holographic screen. The observer itself is nothing more than the perceiving consciousness present at the central point of view of its own holographic world. Everything the observer can perceive in its own holographic world is a form of information encoded on its own holographic screen that is projected like an image from its screen to its own point of view at the center of that holographic world.

Perception always occurs in a subject-object relation. The perceiving subject is the perceiving consciousness present at the central point of view of its own holographic world. The perceivable object is a form of information encoded on the observer's holographic screen. All objects of perception can be reduced to qubits of information encoded on the screen. Perception occurs when forms of information are projected like images from the observer's holographic screen to its central point of view. Perception is really nothing more than the projection of images.



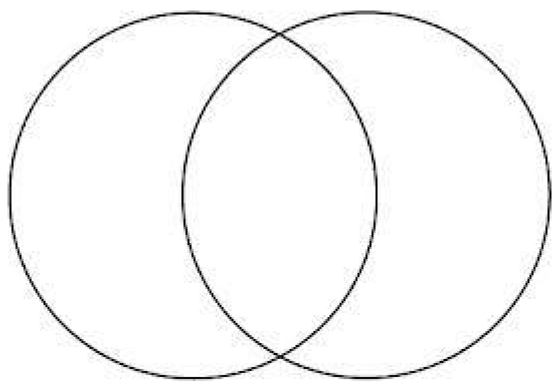
The Observer, the Observer's Holographic Screen and its Object of Perception

The holographic principle is telling us that there really is no such thing as an objective physical reality of the world out there. The world we perceive is a holographic world that is defined on a holographic screen. Every observer observes its own holographic world as defined on its own holographic screen that arises as an event horizon in its own accelerated frame of reference. Everything the observer can perceive in its own holographic world, which is the nature of every object of perception that appears in that holographic world, is a form of information encoded on its own holographic screen and projected like an image from its screen to its own point of view at the center of that holographic world. Everything perceivable can be reduced to qubits of information encoded on its own holographic screen. There is no objective physical reality of the world out there, only qubits of information encoded on the observer's own holographic screen.

In no significant way is this state of affairs any different than what an observer can observe in a computer-generated virtual reality, like depicted in the movie the Matrix. Before we can explain how a computer-generated virtual reality is created, we have to explain how a quantum computer is created that gives rise to the appearance of that computer-generated virtual reality. This is exactly what the holographic principle scientifically explains.

The quantum computer is created when an observer enters into an accelerated frame of reference and an event horizon arises that limits its observations of things in space. The observer's event horizon turns into its holographic screen when it encodes qubits of information. A qubit of information, as mathematically represented by a two dimensional array of numbers called a matrix, can only be encoded on the two dimensional surface of the observer's event horizon, which explains how the quantum computer is created. That quantum computer gives rise to the appearance of the computer-generated virtual reality that the observer perceives.

There are still a few loose ends that we have to wrap up. How do we understand a consensual reality shared by multiple observers, each present at their own individual point of view? The answer is information sharing. Each observer observes the events of its own holographic world as those events are displayed on its own holographic screen that arises as an event horizon in its own accelerated frame of reference, but when those bounding surfaces of space overlap in the sense of a Venn diagram, they can share information, just like the information sharing that occurs in a network of connected computer screens, like the internet. Information sharing explains the nature of the consensual reality shared by multiple observers, each present at its own accelerated point of view at the center of its own holographic world displayed on its own holographic screen. Information sharing is a natural property of the holographic principle, which occurs due to the quantum entanglement of information that arises when qubits of information are encoded on a holographic screen in terms of matrices, just like depicted in the movie the Matrix.



Information Sharing Among Overlapping Holographic Screens

How do we explain the laws of physics that appear to govern events within a holographic world? The way the holographic principle explains the laws of physics is best understood along the lines of the research of Ted Jacobson and Tom Banks. Jacobson was able to show that whenever a holographic world is defined on a holographic screen, that world is governed by the law of gravity in the form of Einstein's field equations for the space-time metric. The space-time metric is the gravitational field, and the law of gravity is understood to arise from the curvature of the space-time geometry of that holographic world. Jacobson understood a holographic screen as an event horizon that arises in an observer's accelerated frame of reference, like a Rindler horizon. When that horizon encodes information along the lines of the holographic principle, and when that horizon has a temperature along the lines of the Unruh temperature, the laws of thermodynamics imply Einstein's field equations for the space-time metric. Einstein's field equations are not really fundamental, but are more like a thermodynamic equation of state that governs whatever events appear to happen inside that holographic world when that world is near thermal equilibrium. The law of gravity is not really fundamental, but is a natural consequence of encoding information on a holographic screen that arises as an event horizon in an observer's accelerated frame of reference and the temperature of that event horizon, which arises from the observer's own accelerated motion. The law of gravity for that holographic world is reducible to the information encoded on the observer's holographic screen and the thermal energy inherent in that holographic world, which arises from the observer's own accelerated motion.

$$R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} = 8\pi GT_{\mu\nu} - \Lambda g_{\mu\nu}$$

Einstein's Field Equations for the Space-time Metric

Tom Banks took Jacobson's work one step further by explaining how information is encoded on the observer's event horizon. The basic idea is what's called a matrix model. Unlike a classical computer, a holographic screen is like a quantum computer. The event horizon is encoding information in terms of qubits, which are quantized bits of information. A qubit of information is mathematically represented by a matrix, like a Pauli spin matrix. A spin ½ variable, represented by a Pauli spin matrix, can only point up or down, and encodes information in a binary code like a switch that is either on or off. Unlike a classical switch, this information is entangled. Quantum entanglement is a natural result of matrices encoding information. In terms of the holographic principle, on the two dimensional surface of a sphere, an SU(2) matrix like a Pauli spin matrix, which is a two dimensional array of numbers, encodes information in a binary code, but that information is encoded in a rotationally invariant way since the SU(2) matrix also gives a mathematical representation of rotational symmetry on the surface of the sphere. Quantum entanglement is a mathematical expression of this rotational symmetry. In general, on the two dimensional surface of any event horizon, it's possible to construct a matrix, which is a two dimensional array of numbers, that encodes information in a binary code. This is the most general way to understand the holographic principle or how event horizons encode information.

The holographic principle tells us that the laws of physics that appear to govern events within a holographic world are not really fundamental, but are more like thermodynamic equations of state that arise when things are near thermal equilibrium. At thermal equilibrium, entropic information becomes maximally disordered under the influence of randomized thermal energy, which is called heat. At thermal equilibrium, when all information is maximally disordered due to the effect of randomized thermal energy, entropic information is the same as thermal entropy. Thermal entropy is defined in terms of the number of thermally randomized dynamical degrees of freedom. The holographic principle tells us that the fundamental nature of a dynamical degree of freedom for a holographic world is a qubit of information encoded on a holographic screen.

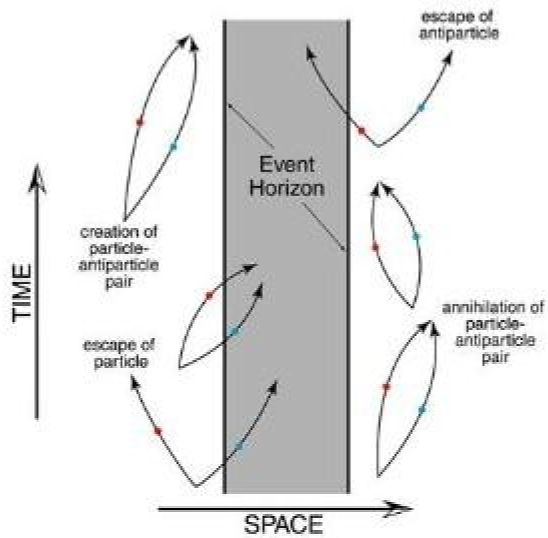
The number of qubits of information encoded on a holographic screen is given in terms of the surface area, A, of that event horizon and the Planck area as $n=A/4\ell^2$. At thermal equilibrium, the number of thermally randomized dynamical degrees of freedom for a holographic world is the same as the number of qubits of information encoded on the holographic screen that displays the images of that holographic world. This fundamentally defines thermal entropy as $S=kn=kA/4\ell^2$.

$$S_{\mathrm{BH}} = \frac{kA}{4\ell_{\mathrm{P}}^2}$$

Thermal Entropy of an Event Horizon

The laws of thermodynamics relate a change in thermal energy, ΔE, to a change in thermal entropy, ΔS, and absolute temperature, T, as $\Delta E=T\Delta S$. This is a very general relationship that arises from the statistical or thermal behavior of things, but it's only valid at thermal equilibrium, when information is maximally disordered. This relation represents the equal partition of energy. At thermal equilibrium, every dynamical degree of freedom carries the same amount of thermal energy, which essentially defines temperature as $E=kT$. The amount of thermal energy carried by each dynamical degree of freedom is defined as $E=kT$. The number of dynamical degrees of freedom is defined in terms of entropy as $S=kn$. If there is a change in entropy as $\Delta S=k\Delta n$, then there is also a change in the total amount of thermal energy as $\Delta E=T\Delta S=kT\Delta n$.

The last thing we need to know is the temperature of an event horizon at thermal equilibrium, which is called the Unruh temperature. Stephen Hawking gave the best explanation for the nature of the Unruh temperature in terms of the apparent separation of virtual particle-antiparticle pairs at the event horizon. As observed by an external observer in an accelerated frame of reference, virtual particle-antiparticle pairs appear to separate at the event horizon. The virtual antiparticle can appear to fall across the event horizon and become unobservable while the virtual particle can appear to become observable as it radiates away from the event horizon towards the external observer. This particle radiated away from the event horizon toward the external observer appears to become a particle of thermal radiation called Hawking radiation, which carries heat. The observer observes heat energy being radiated away from the event horizon as though the event horizon has a temperature. Where does this thermal energy come from? The answer is that thermal energy comes from the observer's own accelerated motion, which gives rise to the appearance of its event horizon in the observer's own accelerated frame of reference. If the observer accelerates with an acceleration, a, the observed temperature of the event horizon is given in terms of that acceleration as $kT=\hbar a/2\pi c$, which is how the Unruh temperature is defined.



Hawking Radiation

At thermal equilibrium, the observer's event horizon appears to have a temperature defined in terms of the observer's own acceleration as kT=ħa/2πc, and that event horizon appears to have a thermal entropy defined in terms of the surface area of that event horizon as $S=kn=kA/4\ell^2$. At thermal equilibrium, the number of thermally randomized dynamical degrees of freedom for the observer's own holographic world is the same as the number of qubits of information encoded on the observer's holographic screen, which arises as an event horizon in its accelerated frame of reference. Jacobson was able to show that Einstein's field equations for the space-time metric, which is the law of gravity that governs gravitational events within that holographic world, is a direct consequence of the laws of thermodynamics, ΔE=TΔS, which is only valid when that holographic world is near thermal equilibrium. The holographic principle is telling us that a change in thermal entropy for that holographic world can only arise from a change in the surface area of the event horizon that bounds that holographic world, which implies a change in the space-time geometry of that holographic world. That dynamical change in the curvature of the space-time geometry of that holographic world, which is the nature of gravity as represented by Einstein's field equations for the space-time metric, arises from a simultaneous change in thermal entropy and energy. Einstein's field equations are not really fundamental, but are more like a thermodynamic equation of state that arises when things are near thermal equilibrium.

How do we explain the other laws of physics, like the electromagnetic and the nuclear forces? The answer is the usual unification mechanisms of modern physics, which are usually explained in terms of extra compactified dimensions of space and the super-symmetry of space. Extra compactified dimensions of space explain the nature of the electromagnetic and nuclear forces in terms of the particles called the photon, gluons, and W and Z particles, while super-symmetry explains the nature of all the matter particles, like the electron, neutrinos and quarks. Unification also explains the nature of the Higgs particle that gives mass to all the matter particles through a process of spontaneous symmetry breaking. Just as the force of gravity is represented by Einstein's field equations for the space-time metric, the electromagnetic and nuclear forces are also represented by field theories, like quantum electrodynamics and quantum chromodynamics. For example, Maxwell's field equations for the photon and Dirac's field equation for the electron naturally arise from Einstein's field equations when extra compactified dimensions of space and super-symmetry are invoked. The problem is that all of these field theories, which describe the events that appear to occur within a holographic world, only have the validity of thermodynamic equations of state, and are only valid near thermal equilibrium. It makes sense to quantize the field theories of the electromagnetic and nuclear forces for small quantum fluctuations around thermal equilibrium, which is why quantum field theory is a useful tool for understanding the nature of the world, but it makes absolutely no sense to quantize Einstein's field equations for the space-time metric, which is why gravity cannot be understood as a quantum field theory.

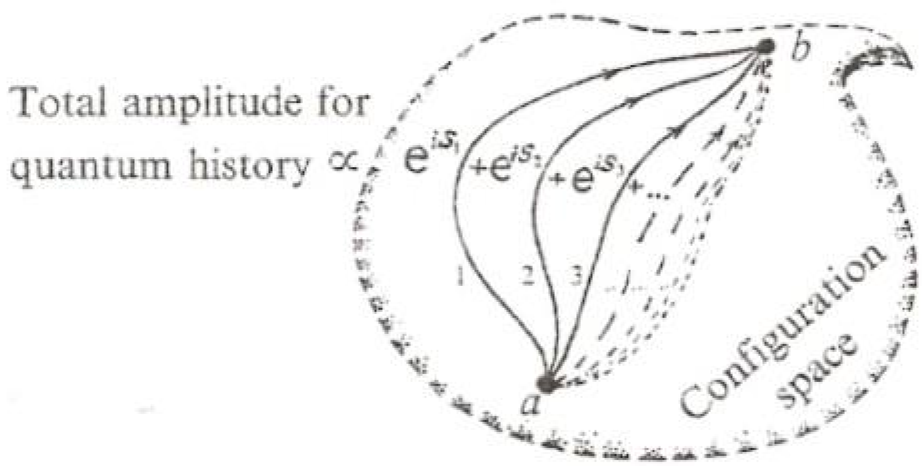
Confusion in theoretical physics arises from the mistaken idea that quantum field theory is fundamental. There is confusion about the nature of the vacuum state. If quantum field theories were really fundamental, then the vacuum state would be characterized as a state of virtual particle-antiparticle pairs. The problem is that this state of virtual particle-antiparticle pairs has to arise in some fixed background space-time geometry, like flat Minkowski space, and so ignores the problem of gravity, which is understood as the dynamical curvature of space-time geometry. At best, quantum field theory only describes a false vacuum state and not the true vacuum state.

All quantum field theories are at best effective field theories that describe small quantum fluctuations around thermal equilibrium, like thermodynamic equations of state. This is exactly what the holographic principle demonstrates. An example of this state of affairs is the Higg's mechanism and spontaneous symmetry breaking. In order to generate the Higg's mechanism, we have to assume that the parameters of the theory are temperature dependent. There is a critical temperature at which the phase transition occurs. As the temperature varies around the critical temperature, the parameters of the theory change sign from positive to negative, which is how the phase transition occurs. This temperature dependence of the parameters of the theory tells us that quantum field theories are only effective field theories, like thermodynamic equations of state, and are not really anything fundamental. Only the holographic principle explains things at a fundamental level in terms of the qubits of entropic information encoded on a holographic screen and the energy inherent in a holographic world. The observer's holographic screen always arises as an event horizon in its own accelerated frame of reference, and the energy inherent in the observer's holographic world arises from the observer's own accelerated motion.

Entropic information does indeed explain the nature of quantum theory and the laws of physics, as long as we understand that entropic information is encoded on the surface of an event horizon that arises in an observer's accelerated frame of reference. Entropic information is encoded on the two dimensional surface of the observer's event horizon in terms of qubits of information, which are mathematically represented by two dimensional arrays of numbers called matrices, which is how the observer's event horizon turns into its holographic screen that displays all the images of its own holographic world. Even the energy that flows through that holographic world can be understood to arise from the energy of the observer's own accelerated motion.

The holographic principle gives a natural explanation for quantum state reduction. The encoding of qubits of information on a holographic screen is inherently entangled, which gives rise to a quantum state of potentiality. When a form of information is projected like an image from the screen to the point of view of the observer, that projection of the image is a state of actuality, which is disentangled, hence a quantum state reduction. Quantum entanglement creates a quantum state of potentiality since qubits do not take on definite values, but with quantum state reduction, the qubits are forced to act like classical bits of information that do take on definite values of 1's and 0's. The observer's holographic screen encodes qubits in an entangled state of potentiality, but with the projection of actual images from the screen to the observer's point of view, those projected images are constructed out of disentangled qubits of information that are forced to take on definite values, just like the digital images projected from a computer screen.

Quantum theory tells us the observed events of that world are not predetermined, but instead are encoded in a quantum state of potentiality, which is best understood as a sum over all possible paths. The observer always has a choice to make about which path to follow. Every event that occurs in that holographic world is a decision point about which path to follow. The most likely path in the sense of quantum probability is the path of least action, which is the classical path that is like the path that measures the shortest possible distance between two points in a curved space-time geometry, but the path of least action is only the most likely path in the sense of quantum probability if choices are made in an unbiased way. If bias arises in the way choices are made, then all bets are off and the quantum state loses its classical predictability.



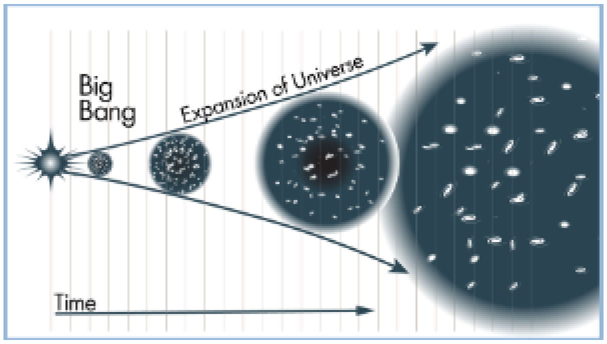
Quantum State of Potentiality as the Sum Over all Possible Paths

As long as all choices are made in an unbiased way, all the events that appear to happen in the observer's holographic world tend to play out in the normal way as all things tend to follow the path of least action. The events the observer perceives in its own holographic world tend to play out normally as energy flows through the observer's holographic world in the normal way.

Normal Flow of Energy Through the Observer's Holographic World

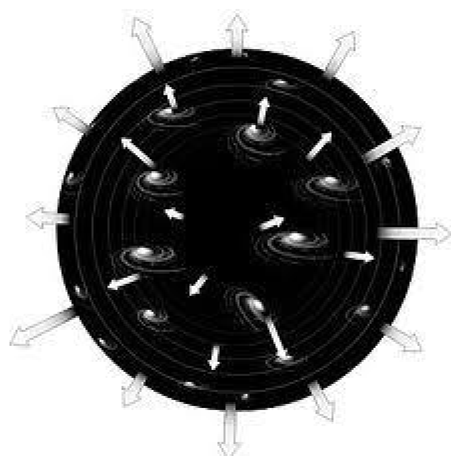
How is the energy that flows through a holographic world created? The thing to be clear about is that the true vacuum state in-and-of-itself expresses no energy and encodes no information. Only with the creation of a holographic world is any energy expressed or information encoded. The true vacuum state is like an empty space of potentiality that has the potential to express energy and encode information, and in that creative process, the space-time geometry of a holographic world is created. The easiest way to understand how energy is created in a holographic world is with the concept of dark energy, which in relativity theory is understood as the accelerated expansion of space that arises from a cosmological constant in Einstein's field equations.

Around the same time that the holographic principle was discovered, the accelerated expansion of the universe was also discovered. It turns out that very distant galaxies are accelerating away from us with a velocity of separation that increases with the distance of separation. It was already known from Hubble's law that distant galaxies are moving away from us with a velocity of separation that increases with the distance of separation, but due to the attractive force of gravity, it was assumed this velocity would decelerate with greater distance. The surprising finding is that this velocity is accelerating with greater distance. This finding is called the exponential expansion of the universe, which is attributed to a mysterious repulsive force called dark energy. It is as though the universe is permeated with this mysterious substance called dark energy that causes the universe to undergo exponential expansion. In relativity theory, this effect is called a cosmological constant, and is attributed to the accelerated expansion of space itself, which is assumed to expand from the big bang event that created the universe.



Accelerated Expansion of the Universe

The simplest way to understand the nature of dark energy is as the accelerated expansion of space itself. The odd thing about dark energy is that this accelerated expansion of space always appears to expand relative to the point of view of an observer at the center of the universe. The point of the big bang that created the universe is literally the central point of view of the observer. Every observer is literally at the central point of view of their own universe, and the accelerated expansion of the universe is literally expanding away from that central point of view.



Accelerated Expansion of Space

This scenario should sound familiar, since it's basically the nature of the holographic principle. Every observer observes the accelerated expansion of the universe relative to its own central point of view at the center of the universe. What we call the universe is really an observer's own holographic world. The accelerated expansion of space that underlies the exponential expansion of the universe places the observer in an accelerated frame of reference. The farther out into space the observer looks, the faster distant galaxies appear to accelerate away from the observer. At some point, the galaxies appear to move away from the observer at the speed of light, which creates a cosmic horizon, and nothing is observable beyond the observer's cosmic horizon.

This scenario is exactly the nature of the holographic principle, which tells us that the observer's cosmic horizon becomes a holographic screen when it encodes qubits of information. Everything the observer can observe in its own holographic world, like a galaxy, can be reduced to qubits of information encoded on its own cosmic horizon. Those objects of perception are forms of information that are projected like images from the observer's holographic screen to its point of view at the center of its own holographic world. Those projected images are animated in the flow of energy that energizes that holographic world, which essentially is the nature of dark energy that gives rise to the accelerated expansion of space in that holographic world. The normal flow of energy through a holographic world can therefore be understood as being due to the expression of dark energy and the accelerated expansion of space in that holographic world. That space is undergoing accelerated expansion relative to the central point of view of the observer of that holographic world. The expression of dark energy is literally the energy that animates the observer's own holographic world. Where does this energy come from? It comes from the same source that the observer's perceiving consciousness comes from. The source of dark energy is the true vacuum state, which is also the source of the observer's perceiving consciousness.

The observer's perceiving consciousness, which perceives its own holographic world from the central point of view of that world, and the expression of dark energy that places the observer in an accelerated frame of reference, which creates that holographic world with the creation of the observer's cosmic horizon that acts as its holographic screen, arise together from the true vacuum state. The true vacuum state is like an empty space of potentiality that has the potential to create dark energy through the accelerated expansion of space, which always expands relative to the central point of view of an observer. The true vacuum state is also the source of the observer's perceiving consciousness, which is always present at a point of view and arises simultaneously with the expression of dark energy. The expression of dark energy places the observer in an accelerated frame of reference, which gives rise to the observer's cosmic horizon that becomes its holographic screen when its horizon encodes qubits of information. The observer's holographic screen is displaying images of the observer's own holographic world that the observer perceives from the central point of view of that world. The creation of that world occurs simultaneously with the observer being present at the central point of view of that world and perceiving that world. The creation and perception of a holographic world are simultaneous events.

The lesson we can learn from the nature of dark energy is that there can be no creation without perception. Creation and perception are simultaneous events. The creation of a holographic world only occurs because the true vacuum state, which is like an empty space of potentiality, has the potential to express dark energy through the accelerated expansion of space. The true vacuum state is also the source of the observer's perceiving consciousness, present at the central point of view of that holographic world. That world appears to undergo accelerated expansion relative to the observer's central point of view. If we understand the observer's perceiving consciousness, present at the central point of view of its own holographic world, as a presence of individual consciousness, the source of that individual consciousness is the true vacuum state, which is like an empty space of pure undifferentiated consciousness. In the process of perceiving its own holographic world, the individual consciousness of the observer has to divide itself from its undivided source of undifferentiated consciousness.

The nature of dark energy gives a natural explanation for the normal flow of energy through the observer's holographic world in the sense of thermodynamics. The size of the world the observer perceives is set by the size of its cosmic horizon, which has a radius R that depends on the amount of dark energy in that world. As the observer's observable world increases in size from the big bang event, its cosmic horizon encodes more qubits of information. A cosmic horizon of radius R has a surface area $A=4\pi R^2$, and encodes $n=A/4\ell^2$ qubits of information. As the observer's world increases in size, the radius to its cosmic horizon increases and more qubits are encoded on its cosmic horizon. The observer's cosmic horizon also has an Unruh temperature given in terms of its radius as $kT=\hbar c/2\pi R$. As the observer's observable world increases in size, the Unruh temperature of its cosmic horizon decreases while the thermal entropy, $S=kn$, of its cosmic horizon increases. In the sense of thermodynamics, this drives the normal flow of energy through the observer's holographic world as the thermal entropy of that world increases and heat flows from hotter to colder objects as the Unruh temperature of its cosmic horizon decreases.

The universe is not at thermal equilibrium because space is expanding in the universe at an accelerated rate. The accelerated nature of the expansion of space, called dark energy, is the primordial energy that puts the *bang* in the big bang event. The whole idea of the creation of the universe in a big bang is based on the idea of the accelerated expansion of space. As is well known, the accelerated expansion of space implies a cosmic horizon that limits the observations of the observer at the central point of view of that bounding surface of space. The holographic principle tells us the observer's cosmic horizon defines its own holographic world whenever space expands since that is where all the fundamental qubits of information for that world are encoded. Inherent in the idea of the big bang is the idea the observer's observable world increases in size as space expands. This implies the observer's cosmic horizon increases in radius as the observer's world increases in size. As the observer's cosmic horizon increases in radius, its Unruh temperature cools, which explains the normal flow of heat in the observer's world as heat flows from hotter to colder objects. This also explains the second law of thermodynamics which says entropy tends to increase as heat flows in a thermal gradient. As the observer's cosmic horizon increases in radius, its Unruh temperature cools, but its surface area increases, which implies the thermal entropy of the observer's world increases even as its world cools, since more qubits of information are encoded on the observer's cosmic horizon. The normal flow of heat in the thermal gradient created as the observer's world increases in size with the expansion of space explains the direction of *time's arrow* and the normal flow of energy through the observer's holographic world. The direction of *time's arrow* is literally directed in the direction of the accelerated expansion of space in the observer's holographic world that gives rise to the creation of the universe as a holographic world. At thermal equilibrium, information becomes more disordered and thermal entropy takes on its maximal value. As the observer's cosmic horizon increases in size toward infinity, its temperature approaches absolute zero and its holographic entropy approaches infinity, which is called the *heat death* of the universe.

That's basically the whole story of the holographic principle. Whenever an observer enters into an accelerated frame of reference, an event horizon arises that limits the observer's observations of things in space. The observer's event horizon acts as its holographic screen when that horizon encodes qubits of information. This encoding of information is understood to mathematically arise in terms of matrices, which are two dimensional arrays of numbers defined on the two dimensional surface of the observer's event horizon. That encoding of qubits of information on the observer's event horizon is how a quantum computer is created that gives rise to the appearance of a computer-generated virtual reality. There really is no such thing as an objective physical reality of the world out there, only a computer-generated holographic virtual reality that is reducible to qubits of information encoded on the observer's own holographic screen, which arises as an event horizon in its own accelerated frame of reference, and the energy that flows through that holographic world, which arises from the observer's own accelerated motion.

Everything the observer can observe in its own holographic world is reducible to the information encoded on its own holographic screen and the energy that flows through its own holographic world. Everything the observer can observe in its own holographic world is like a holographic image projected from its own holographic screen to its own point of view at the center of that holographic world. Those holographic images are animated in the flow of energy that flows through that holographic world, which is the same energy that flows through the quantum computer. That energy arises from the observer's own accelerated motion. The observer itself is the consciousness present at the central point of view of that holographic world. In no significant way is this scientific explanation any different from that of a computer-generated virtual reality, like depicted in the movie the Matrix. This is inherently an observer-centric description of observable reality, which in reality is no more real than the projected and animated images of a computer-generated virtual reality. Everything the observer can perceive in its own holographic world is imaginary in the same sense as the projected and animated images of a holographic world. Only the consciousness of the observer, present at the central point of view of its own holographic world, is really real and has its own independent existence and reality. Although this is hard for most people to accept, only consciousness itself is really real. Everything perceivable in the observer's holographic world is part of the computer-generated virtual reality and is unreal. In the words of the Bhagavad-Gita, *The unreal has no being; the real never ceases to be*.

Physics isn't about the world because there really is no such thing as an objective physical reality of a world out there. Physics is about the information encoded on an observer's holographic screen that gives rise to the appearance of the observer's holographic world as a computer-generated virtual reality whenever the observer's perceiving consciousness, present at the central point of view of its own holographic world, enters into an accelerated frame of reference. There really is no world. Only the consciousness of the observer really exists, and the observer's world only appears to come into existence due to the observer's own motion.

Do not try to bend the spoon. That is impossible. Only try to realize the truth.
What truth?
There is no spoon.
Then you'll see it is not the spoon that bends, but only yourself.

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