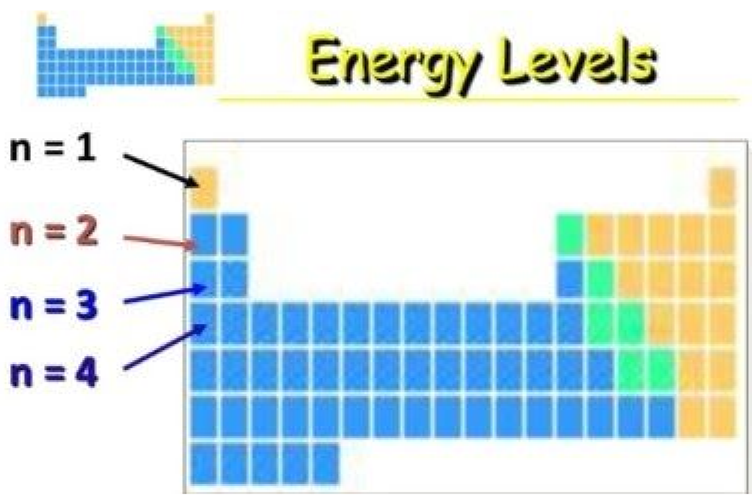
An Introduction to Atomic Theory and its Relation to the Holographic Principle and the Mystery of Creation

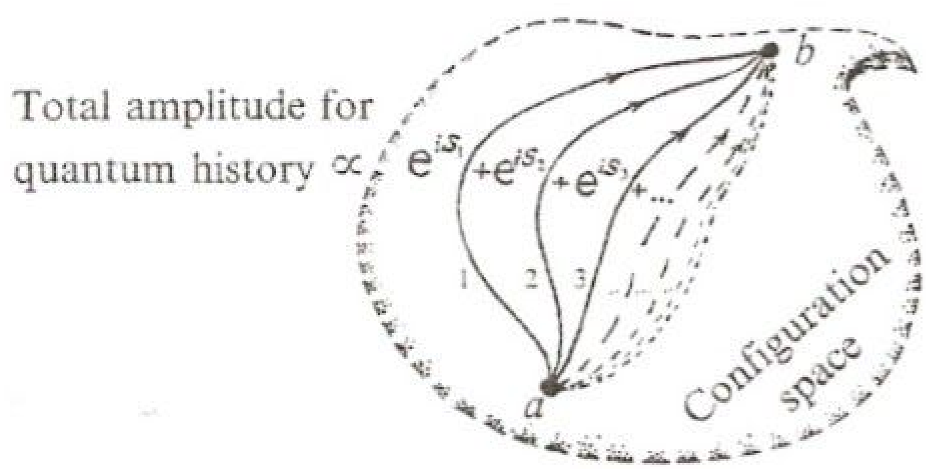
Elements are all atoms, as in the periodic table of elements. An atom is an atomic nucleus surrounded by a cloud of electrons, which bind to the nucleus in electron orbitals under the influence of the electromagnetic force. An atomic nucleus is a bound state of protons and neutrons, which bind together under the influence of strong nuclear force, but can be further deconstructed into quarks and gluons, just as the electromagnetic force can be deconstructed into photons. Inside the atomic nucleus, the attractive strong nuclear force between protons and neutrons is short-ranged, and is opposed by the long-ranged repulsive electromagnetic force between protons. At some point, the short-ranged nuclear attraction between protons and neutrons is overcome by the long-ranged electromagnetic repulsion between protons, and the atomic nucleus falls apart. That's what drives the explosive energy of an atomic bomb. Another complicating factor is the weak nuclear force that turns a neutron into a proton, electron and neutrino. The electron and neutrino fly away from the nucleus, but if the atomic nucleus has too many protons, it falls apart. That's the basic reason the periodic table comes to an end. Too many protons inside the nucleus and electromagnetic repulsion overcomes strong nuclear attraction.



Periodic Table

In terms of what is actually measured in the universe, we can only go by patterns of measured atomic spectra. Each atom has a characteristic atomic spectra as an electron makes a transition from one atomic orbital to another atomic orbital and a corresponding photon is either emitted or absorbed. These photon emission spectra are what's actually measured, and each atom has its own characteristic spectrum. All the atomic spectra that can be measured in the universe can be reproduced on earth in terms of the known elements of the periodic table. A caveat is the unstable elements that only hold together for microseconds, which can be studied in the physics lab and could be measured in terms of atomic spectra from stars and galaxies. These elements are unstable because they have too many protons inside their atomic nuclei, but under the right conditions, they can hold together for a very short period of time. The periodic table only includes the stable atoms that are stable under normal earth-like thermodynamic conditions. Unstable atoms might be stable for a short period of time under the right conditions, like the high pressures and temperatures found inside a star or other stellar objects like a nebula.

When we talk about things thermodynamically, like the stability of atoms, we're assuming unbiased or random choice. Thermodynamics assumes events occur randomly. Once we allow for the possibility of biased choice, then all bets are off and anything is possible because the quantum state of potentiality allows for all possible outcomes, not just the classical outcome. The way quantum theory expresses this potentiality is in terms of the quantum state, which can always be formulated as a sum over all possible paths in some information configuration space.



Quantum State as the Sum Over All Possible Paths

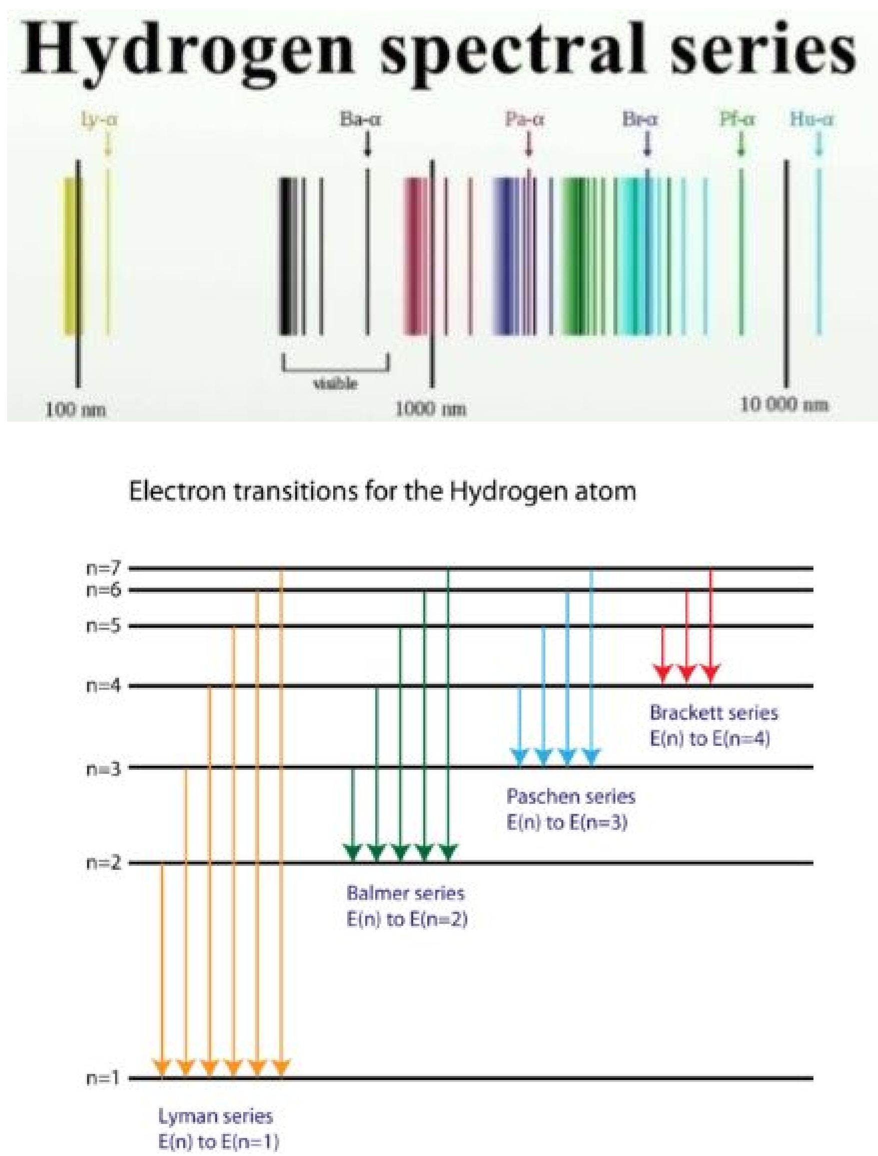
Thermodynamic stability is a concept like the normal flow of things, which arises in terms of choosing things from the quantum state of potentiality in an unbiased or random way. The laws of physics only enter into the quantum state as an action principle, which determines quantum probability. Quantum probability is determined by the quantum wave function, which in turn is determined by an action principle. All laws of physics can be expressed as an action principle.

Action is like a measure of distance along some path between two points in some information configuration space. The most likely outcome in terms of quantum probability is the path of least action, which is like the shortest possible distance between those two points in the information configuration space. That's why events seem to obey classical laws of physics, but there is an important caveat. If there is bias in the way choices are made, then the laws of physics lose their classical predictability. In the sense of throwing dice, to use Einstein's famous analogy, if the dice are loaded, the game is rigged and all bets are off. Bias in the way choices are made could turn what would otherwise be an unstable atom into what appears to be a stable atom. If enough bias is expressed in the way choices are made, one could through the force of one's own will or focus of attention turn what would otherwise be an unstable atom into a stable atom, at least for the short period of time one's attention is focused on that task. This is the same explanation for how one learns to levitate one's body and in effect bend the law of gravity. In the Matrix, Morpheus tells Neo the law of gravity is based on computational rules, just like the rules that govern the operation of a computer, but by the force of one's own will or focus of attention, one can bend or break the rules. This could also apply to turning an unstable atom into a stable atom.

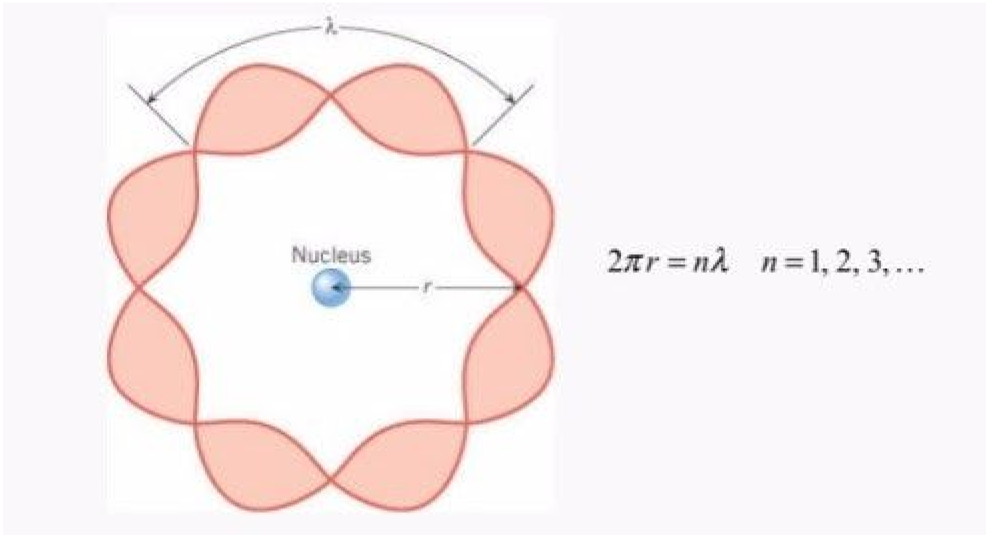
The point particle formulation of quantum theory is inherent in the quantum field theory of the standard model of particle physics. The electromagnetic force is described by the quantum electrodynamics of photons and electrons, the strong nuclear force by quantum chromodynamics of quarks and gluons, and the weak nuclear force by the weak theory of W and Z particles and neutrinos. The electromagnetic force is attractive between opposite charges and repulsive between like charges, and is long-ranged because the photon, which is the exchange particle of the force, has no mass. The strong nuclear force is complicated because of quark confinement.

Basically, the gluons, which are the exchange particles of the strong force, line up into long linear string-like structures that bind the quarks into either protons or neutrons, which are bound states of 3 quarks, or a quark-antiquark pair that is called a pi meson. The pions are the effective exchange particles of the strong nuclear force, which attract the protons and neutrons together inside the atomic nucleus. The strong force is purely attractive and is more powerful than the electromagnetic force, but it's short-ranged because the pion has a small mass. The distance over which the pion is active is about the radius of an atomic nucleus, which is why the nucleus falls apart if it gets too big and there are too many protons inside that electrically repel each other. All this activity happens pretty much out of sight because of quark confinement. The quark activity can only be detected in particle accelerators, which requires very high energies.

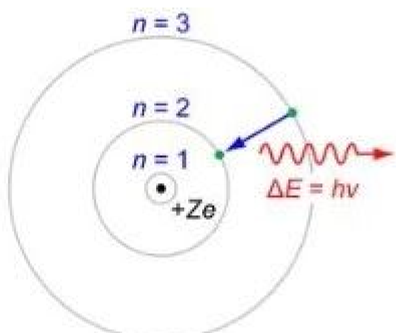
The stuff we can see is when an electron makes a transition from one quantized electron orbital to another electron orbital in an atom, which is a bound state of the electrons with the atomic nucleus. Only the electromagnetic force is active at that level. What we actually see are spectral lines that correspond to such an electron transition. These spectral lines are photons emitted from the atom at a single quantized energy level. The atomic spectrum that is characteristic of each atom is a sequence of such spectral lines. Each spectral line has its own inherent frequency that is characteristic of that specific atom. Since the energy of the emitted photon is quantized in terms of its frequency as E=hf, by measuring the frequency of the photon, we know what atom it came from. That energy arises from the difference in the quantized energy levels of atomic orbitals that characterize that specific atom, which arises as the electron makes a transition between two orbitals, which is to say $E=E_1-E_2$. The atomic orbitals are quantized in energy because the bound state electron wave function has to fit an integer number of wavelengths along the circumference of the atomic orbital, which means the frequency of the electron's wave function is fixed at a certain quantized frequency for each atomic orbital. This means we can write $E_1=hf_1$ and $E_2=hf_2$, and so the frequency of the emitted photon is given as $f=f_1-f_2$.



Spectral Lines Emitted as Atomic Orbital Electron Transitions

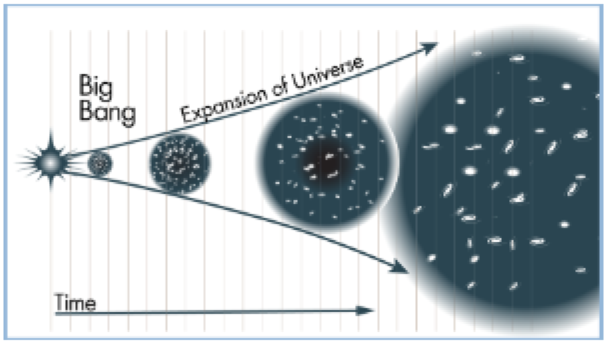


$$Mvr = \frac{nh}{2\pi} \quad \text{where } Mv = \frac{h}{\lambda} \quad \text{that results in} \quad 2\pi r = n\lambda$$



Bohr Atomic Orbitals and Electron Transitions

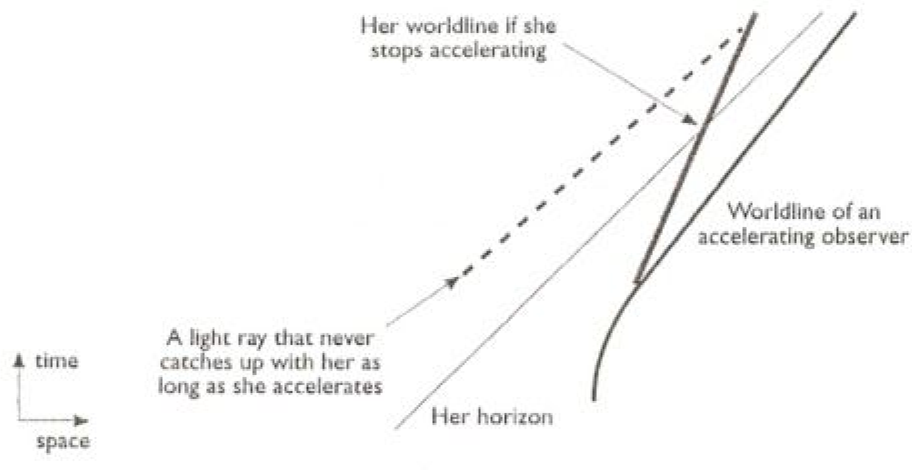
That's basically how atomic theory works. Once we know these inherent frequencies of the atomic orbitals that characterize specific atoms, we can then use that knowledge to deduce a number of other things we observe in the universe. The expansion of the universe is deduced from the Doppler effect by measuring the red shift in the frequencies of spectral lines, which is proportional to the velocity of separation. Hubble's law for the expansion of the universe basically says that the velocity of separation, which is deduced from the red shift, is proportional to the distance of separation, as deduced from other measurements, like the absolute magnitude or luminosity of a certain type of supernova. In relativity theory, this expansion of the universe is understood as the expansion of space. The most fundamental equation we have for energy at the level of particle physics is E=hf, which relates the energy of a particle, like a photon, to the frequency of its wave function. This is also true for massive particles like the electron.



Big Bang as the Expansion of Space

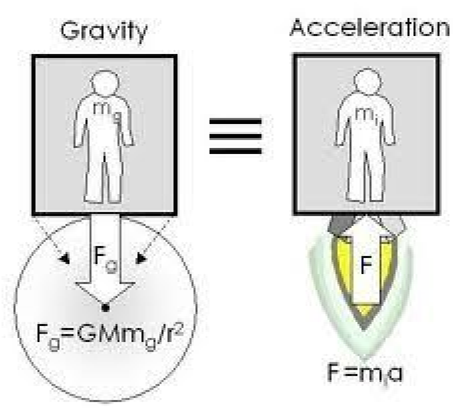
The problem of mass is complicated because of the Higgs phenomena. $E=mc^2$ is not really a fundamental equation. The mass of all particles arises through the Higgs phenomena, which is like a phase transition that turns water into ice, but the more accurate analogy is turning a bunch of charged spinning particles like electrons, each of which has an intrinsic magnetic field, into a macroscopic magnet when all the microscopic magnetic field lines line-up together. The Higgs phenomena is like generating a macroscopic magnetic field from the lining-up of a large number of microscopic little magnets. For reasons that are inherent to the mathematical structure of quantum field theory, that process gives the other fields coupled to the Higgs field a mass even if the other fields started out being massless. Mass is not really a fundamental attribute of matter, but spontaneously emerges through a phase transition as the Higgs field develops a macroscopic value in space, like the macroscopic value of a magnetic field that spontaneously develops with the magnetization of a magnet. This happens as the temperature of the universe becomes cool enough, just like a magnet spontaneously magnetizes as the metal cools. If the temperature is too hot, the microscopic magnets inside the metal don't line-up together, but at a certain critical temperature characteristic of the phase transition, like the freezing point of water, the microscopic magnets line-up as the metal cools. This macroscopic value of the Higgs field is characterized by a certain frequency of its wave function. Since energy is quantized in terms of frequency, $E=hf$, that energy is what gives the other particles coupled to the Higgs field their mass as $E=mc^2$. In this sense, mass is only a disguised form of frequency that arises through the Higgs effect. This is called spontaneous emergence, since it happens as a phase transition as the universe cools. At higher temperatures, all particles are massless, just like the photon.

This whole scientific story is based on the point particle formulation of quantum theory, which is inherent in quantum field theory. The problem is quantum field theory is not really fundamental. Quantum field theory can be deduced from the holographic principle. At a more fundamental level, a point particle apparently existing in space and time is a holographic illusion. The fundamental nature of the universe is quantized bits of information, called qubits, encoded on a holographic screen. That's what makes the universe a holographic universe. The holographic screen in turn is an event horizon that arises in an observer's accelerated frame of reference. The accelerating observer's event horizon is a bounding surface of space that limits the observer's observation of things in space due to the constancy of the speed of light for all observers, independent of their individual state of motion. Every observer in an accelerated frame of reference has an event horizon that limits the observer's observation of things in space.



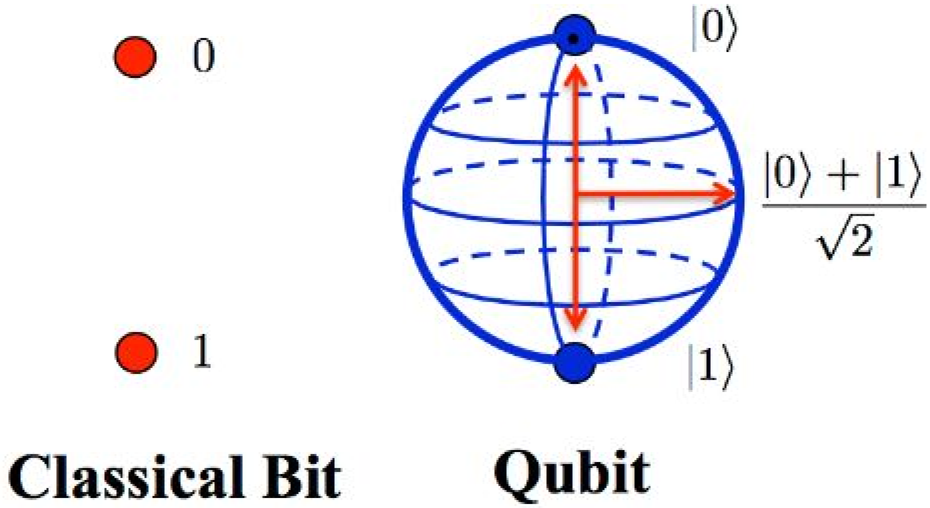
Accelerating Observer's Event Horizon

In relativity theory, an accelerated frame of reference is equivalent to the exertion of a force, which is known as the principle of equivalence. 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. There is no way to distinguish the effect of an acceleration from the exertion of a force.



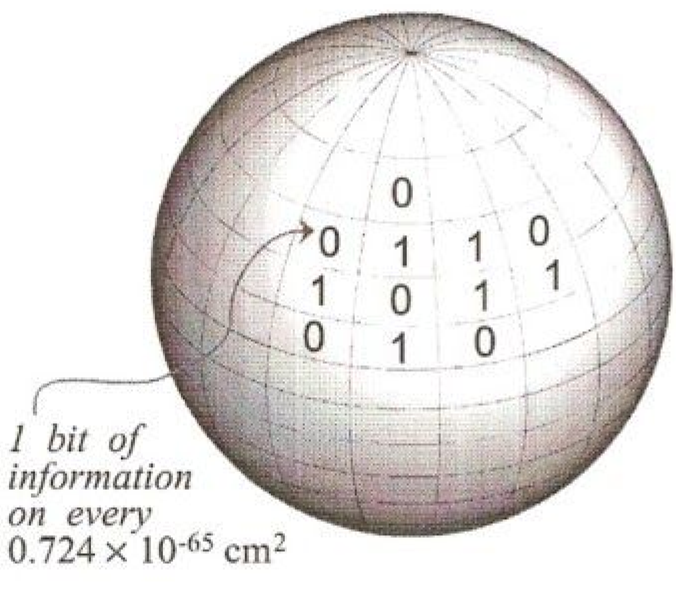
Principle of Equivalence

The easiest way to understand how qubits of information are encoded on the observer's event horizon, which turns the horizon into a holographic screen, is with non-commutative geometry, which explains how space-time geometry is quantized. Each quantized position coordinate on the observer's event horizon is smeared out into an area element like a pixel that encodes a quantized bit of information as a qubit. In quantum gravity, the pixel size is called the Planck area.



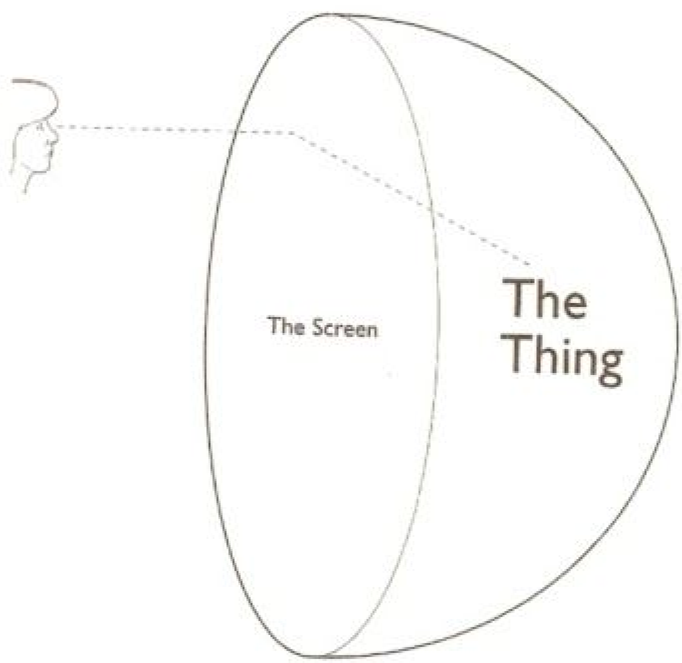
Qubit as the Information Encoded on a Planck Size Event Horizon

This gives the observer's event horizon an entropy as S=kn, where n is the number of qubits encoded on the event horizon and is proportional to the surface area A of the horizon as $n=A/4\ell^2$, where $\ell^2=\hbar G/c^3$ is the Planck area. Each Planck area on the horizon acts like a pixel that encodes a qubit of information. Non-commutative geometry fundamentally explains how the qubits are encoded on a holographic screen in terms of quantizing position coordinates on the screen, which smears out each quantized position coordinate into an area element like a pixel that encodes a qubit of information. This value for entropy of the observer's event horizon given in terms of the number of qubits of information encoded on the horizon is called the holographic principle.



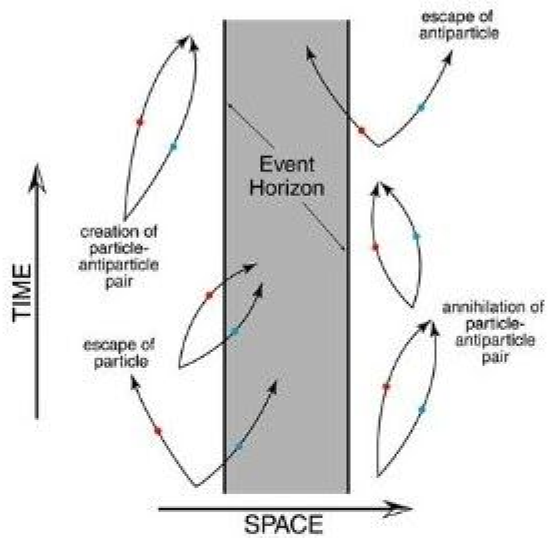
Holographic Principle

The holographic principle basically says that every accelerating observer has its own holographic world defined on its own holographic screen that arises as an event horizon in the observer's accelerated frame of reference. The observer's holographic screen is where all the qubits of information for everything observable in the observer's world are encoded. Things don't really exist in three dimensional space. In some sense, everything observable in three dimensional space is a holographic illusion that arises as a holographic form of information for that thing is projected like an image from the observer's holographic screen, which is a two dimensional bounding surface of space, to the observer's central point of view in space, which always arises in relation to that holographic screen. The observation of things appearing in three dimensional space is a holographic illusion that results from holographic projection. This even applies to elementary particles, like photons and electrons. All the fundamental qubits of information for an elementary particle are encoded on the observer's holographic screen. The observer's observation of an elementary particle, like anything else it can observe in its holographic world, is only the observation of a form of information projected like an image from the observer's holographic screen to its central point of view. Everything observable arises through holographic projection.



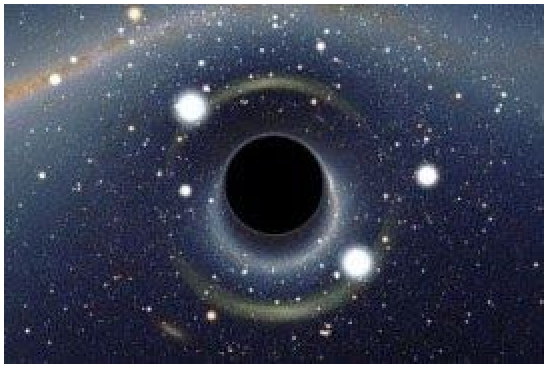
The Observer, the Screen and the Thing

The energy that flows through the observer's holographic world also arises in the observer's accelerated frame of reference. This energy is given in terms of the Unruh temperature as $E=kT$, which is proportional to the observer's acceleration, a, as $kT=\hbar a/2\pi c$. The Unruh temperature arises as the temperature of thermal radiation the accelerating observer observes emitted from its event horizon. This thermal radiation arises from separation of virtual particle-antiparticle pairs at the observer's event horizon as observed by the observer in its accelerated frame of reference.



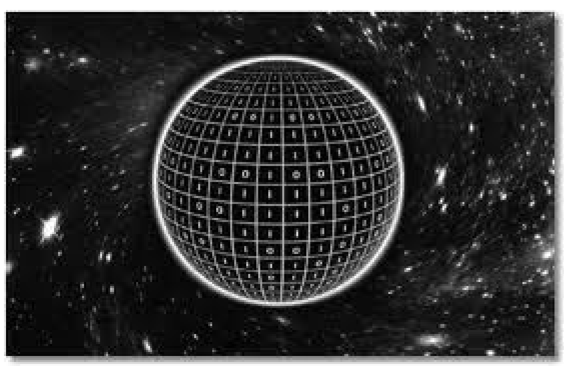
Hawking Radiation

Thermal radiation appears to be radiated away from the accelerating observer's event horizon, which is called Hawking radiation, but is only observed by the accelerating observer. Hawking radiation is confusing since it mixes up concepts of the holographic principle with the quantum field theory formulation of point particles. In quantum field theory, uncertainty in energy allows virtual particle-antiparticle pairs to become created within the vacuum state for a short period of time. The virtual pairs are created out of nothing and then normally annihilate back into nothing, but from the point of view of an accelerated observer, something weird appears to happen. The accelerated observer's observations of things in space are limited by its event horizon. At the observer's event horizon, the virtual particle-antiparticle pairs can appear to separate. One member of the pair can disappear behind the event horizon while the other member of the pair can appear to be radiated away from the event horizon toward the observer. The observer observes this radiated particle as a particle of thermal radiation, which gives its event horizon an apparent temperature. The observer's event horizon is acting as a holographic screen that encodes qubits of information for all the point particles that can appear in the observer's world through holographic projection, but the separation of virtual particle-antiparticle pairs at that event horizon gives the observer's event horizon an apparent temperature that's proportional to the observer's acceleration. In quantum field theory, the virtual particle-antiparticle pairs are entangled. This implies the entropy of the observer's event horizon is an entanglement entropy. This is consistent with the holographic principle as understood with non-commutative geometry since all the qubits of information encoded on the observer's event horizon are also entangled.



Black Hole

The holographic principle is telling us about a peculiar symmetry that's inherent to the nature of gravity. This symmetry is called conformal symmetry or Weyl invariance, which is the symmetry of objects appearing self-similar when observed at different length scales. Conformal symmetry expresses invariance of the laws of physics as the space-time metric is transformed with a new length scale. The law of gravity as reflected by Einstein's field equations for the space-time metric has no inherent length scale. This gives rise to the gravitational acceleration of a massive body falling off as $1/R^2$ at a radial distance R from the massive body. The holographic principle was first discovered for black holes, which are defined by an event horizon of radius R. At the event horizon, the acceleration due to gravity is $a=GM/R^2$, where M is the mass of the black hole and R is the radius of its event horizon. A stationary observer hovering just outside the event horizon of a black hole must accelerate away from the black hole with an equal but opposite acceleration to maintain its stationary position. The Unruh temperature of the event horizon as observed by the accelerating observer, $kT=\hbar a/2\pi c$, is proportional to the observer's acceleration $a=GM/R^2$. The entropy, $S=kn=kA/4\ell^2$, of the event horizon is proportional to its surface area $A=4\pi R^2$.



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

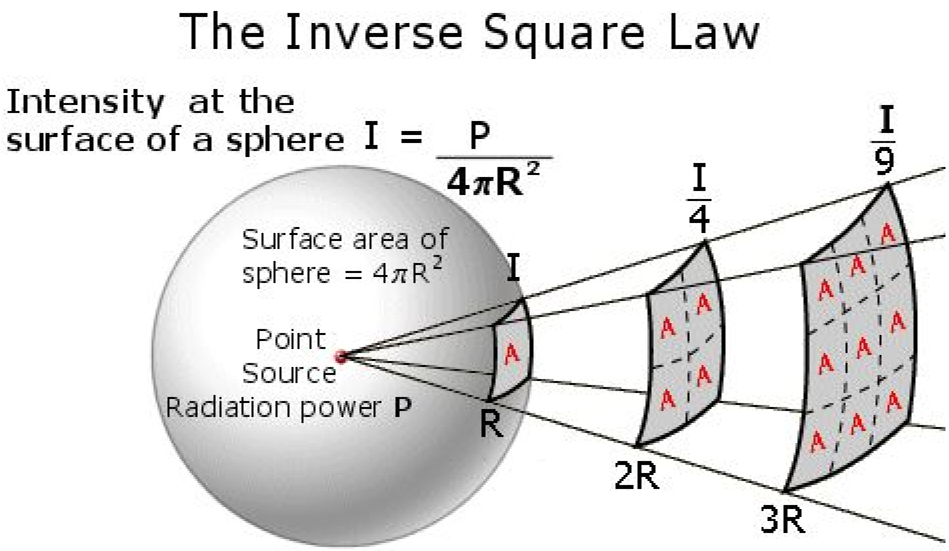
Black Hole Entropy

It's not a coincidence that the entropy of the event horizon behaves like R^2 while the Unruh temperature behaves like $1/R^2$. The total energy of the black hole is given in terms of its mass as $E=Mc^2$. The laws of thermodynamics relate a change in total energy to temperature and a change in entropy as $\Delta E=T\Delta S$. In terms of the holographic principle, the fundamental reason for this relation between energy and entropy is each qubit of information encoded on the observer's holographic screen inherently carries an amount of thermal energy $E=kT$ given in terms of the Unruh temperature. Each qubit of information is a fundamental dynamical degree of freedom for the observer's holographic world. As more qubits of information are encoded on the observer's holographic screen, more energy is inherent in that holographic world. This relation is explicitly demonstrated for a black hole. If we imagine changing the mass of the black hole by ΔM, we change its total energy by $\Delta E=\Delta Mc^2$. Thermodynamics tells us this should be equal to $T\Delta S$, where $\Delta S=k\Delta n=k\Delta A/4\ell^2=k8\pi R\Delta R/4\ell^2$. At this point we need to know the radius R of the event horizon in terms of the mass M of the black hole. Einstein's field equations give the answer as $R=2GM/c^2$. This gives $\Delta S=k16\pi RG\Delta M/4\ell^2c^2$. The Unruh temperature is $kT=\hbar GM/R^2 2\pi c$, and so we can finally write $T\Delta S=(16\pi RG\Delta M/4\ell^2c^2)(\hbar GM/R^2 2\pi c)=\hbar G(2GM/Rc^2)\Delta M/c\ell^2=\hbar G\Delta M/c\ell^2$. If we equate this expression to $\Delta E=\Delta Mc^2$, we then discover the Planck area is given by $\ell^2=\hbar G/c^3$.

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

Planck Length

The key idea is the entropy of the event horizon is an area law that behaves like R^2, while the Unruh temperature of the event horizon is an acceleration that behaves like $1/R^2$, and so these two factors cancel each other out. We're assuming three dimensional space where the surface area of a spherical event horizon is proportional to R^2. There's a simple physical explanation for why the acceleration due to gravity behaves like $1/R^2$. If we imagine the force of gravity is due to the exchange of a force particle called the graviton and that a mass acts like a point source of gravitons constantly emitted in all directions, then the total flux of gravitons that pass through a spherical surface of radius R must be constant, and so the force of gravity falls off as $1/R^2$. The force of gravity between two masses is proportional to the number of gravitons exchanged and falls off as $1/R^2$ since the total flux of gravitons passing through a spherical surface is constant.

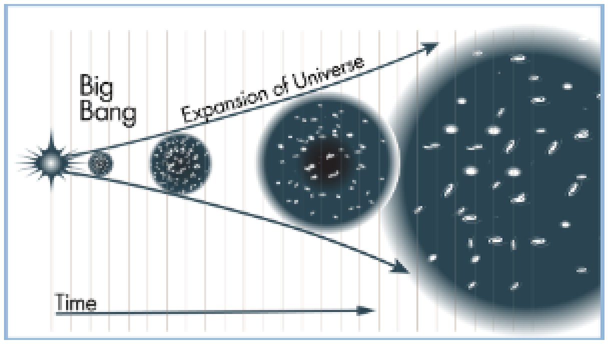


The event horizon of a black hole is a special spherical surface where the escape velocity from that surface is the speed of light. A simple way to calculate the radius of the event horizon using classical concepts is to equate the kinetic energy of a particle of mass m moving away from a mass M with a velocity v, $KE=\frac{1}{2}mv^2$, with the gravitational potential energy of that particle at a distance R from the mass M, $PE=GmM/R$. With escape velocity, the mass m has just enough kinetic energy to overcome the gravitational attraction of the mass M. This determines escape velocity as $v^2=2GM/R$. If we equate $v=c$, we find the radius of the event horizon is $R=2GM/c^2$, which is to say the escape velocity at the event horizon of a black hole is the speed of light.

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

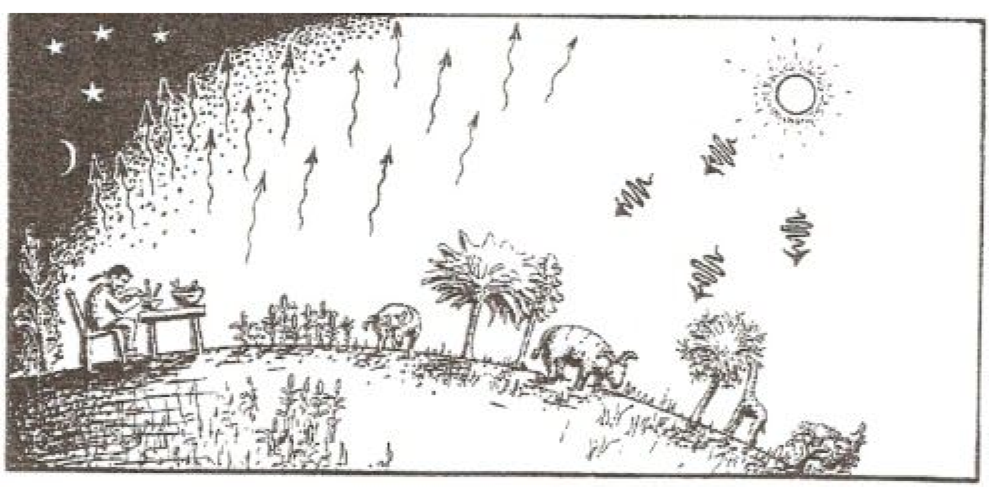
Schwarzschild Radius

The speed of light is also the speed that a graviton travels through space since the graviton is a massless particle, like the photon. The idea of the holographic principle is to encode qubits of information for gravitons on the surface of an event horizon that acts as a holographic screen. In order to keep the flux of gravitons through the surface constant, independent of the radius of the surface, the number of pixels on the surface, each of which encodes a qubit of information, must be proportional to the surface area. The holographic principle reflects that the total flux of gravitons through a spherical surface is constant when the gravitons are emitted from a point source at the center of that surface, which implies the $1/R^2$ force law, and that each graviton can be reduced to a qubit of information encoded on the special surface of an event horizon, which implies the area law for entropy. Entropy is the total number, $n=A/4\ell^2$, of qubits encoded on the event horizon needed to characterize all the gravitons. The acceleration due to gravity enters into the Unruh temperature as a way to insure that the laws of thermodynamics are satisfied.



Expansion of Space

The idea of creation of the universe in a big bang is based on the idea of the expansion of space. As is well known, the 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 world whenever space expands. The idea of the big bang is based on this idea of the expansion of space. Inherent in the big bang is the idea the observer's 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 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.



Normal Flow of Energy Through the Observer's Perceivable World

The holographic principle gives us a perfectly good explanation for how the observer's world is created, either in terms of the observer's accelerated motion in its accelerated reference frame or in terms of the expansion of space, which defines a different kind of accelerated reference frame. In either case, everything the observer can observe in its world arises through holographic projection, as a form of information is projected like an image from the observer's holographic screen to its central point of view. The observer's holographic screen always arises as an event horizon in its own accelerated frame of reference. That event horizon acts as a holographic screen in the sense of encoding qubits of information, which are the fundamental dynamical degrees of freedom of its own holographic world. Everything perceivable in its holographic world is a form of information constructed out of qubits encoded on the observer's holographic screen. Even the flow of energy that animates those forms of information is inherent in the observer's own accelerated frame of reference in the sense of thermodynamics and the Unruh temperature of its event horizon. In this sense, every perceivable thing is a holographic illusion.

Everything perceivable is a holographic illusion. The perceivable things aren't really real. Even the apparent 3+1 dimensional space-time geometry of the world is a holographic illusion. Just like all other perceivable things, space-time geometry can be reduced to qubits of information encoded on a holographic screen, and the perception of space-time geometry is no more real than forms of information projected like images from the screen to the observer's central point of view. The apparent space-time geometry the observer observes in its world has no independent existence. If the observer doesn't observe it, that space-time geometry doesn't really exist. Only the observer is real and has its own independent existence. Everything the observer observes in its world, including the space-time geometry of that world, is dependent on the observer's observation of it before it can appear to come into existence. If the observer does not observe it, it does not exist, except in the sense of an unobserved state of potentiality. That's exactly what quantum theory tells us. The observation of space-time geometry, just like anything else the observer can observe, is only an illusion of existence in the sense of holographic projection.

Most physicists cannot accept this state of affairs since space-time geometry, like everything else that can be perceived in the observer's world, appears to obey computational rules. The space-time geometry of the observer's world appears to obey the computational rules inherent in Einstein's field equations for the space-time metric. How can something that's not really real and doesn't really exist obey computational rules? The simple answer is, that's the inherent nature of a holographic world. The holographic appearance of that world is constructed out of the qubits of information encoded on a holographic screen, and that holographic construction process obeys computational rules, like the rules that govern the operation of a computer. The computational rules that govern the holographic appearance of the 3+1 dimensional space-time geometry of the observer's world aren't even exact. These rules arise as thermodynamic equations of state and are only an approximation with a limited range of validity in the sense of thermodynamics, which only gives an approximate thermal average description of the observer's world.

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

Einstein's Field Equations for the Space-time Metric

When the observer observes a particle located at some position in space and the motion of that particle through space over the course of time, the observer is really only observing a form of information projected like an image from its own holographic screen to its own point of view and animated over a sequence of holographic projections, just like the animation of the projected images of a movie from a computer screen to an observer. The reason we can say this with confidence is because we can deduce all of quantum field theory from the holographic principle.

To begin with, we can deduce Einstein's field equations for the space-time metric, which is the nature of gravity, from the holographic principle. Einstein's field equations are thermodynamic equations of state that arise from the laws of thermodynamics that relate energy to entropy and temperature, $\Delta E=T\Delta S$. Ted Jacobson has shown how this derivation goes forward in terms of the area law for the entropy, $S=kn=kA/4\ell^2$, of an event horizon and the Unruh temperature of that event horizon, $kT=\hbar a/2\pi c$, as observed by the accelerating observer in its accelerated frame of reference. Once we have Einstein's field equations, all the quantum fields of the standard model of particle physics can then be deduced as extra components of the space-time metric with the usual unification mechanisms of extra compactified dimensions of space and super-symmetry. The whole thing of the quantum field theory formulation of particle physics and the relativistic space-time geometry formulation of gravity can be deduced from the holographic principle.

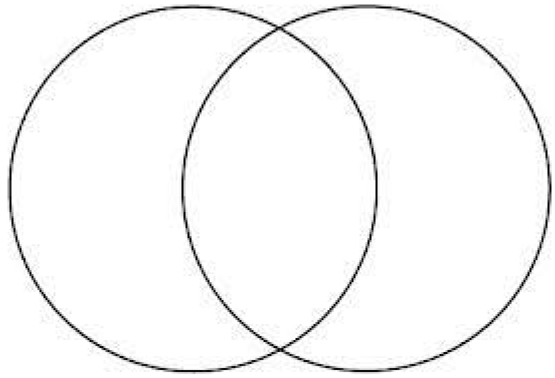
All we really need to explain the whole thing is an observer in an accelerated frame of reference, which gives rise to an event horizon. Apply non-commutative geometry to that event horizon as a way to quantize position coordinates on the horizon, and we have an explanation for how all the qubits of information that describe everything in a holographic world are generated. This includes all the so-called elementary particles of that world that underlie the electromagnetic, strong and weak nuclear forces, but it also includes the space-time geometry of that world that underlies the effect of gravity. Everything observable is a form of information animated in the flow of energy. In the sense of holographic projection, those forms are projected like images from a holographic screen to the observer's central point of view that arises in space relative to the screen, and those forms are animated in the flow of energy, like the animated frames of a movie. With the Unruh temperature of the observer's event horizon we even have an explanation for how energy flows through that holographic world in the sense of thermodynamics. The Unruh temperature feeds back into the point particle formulation of quantum theory since it arises from the apparent separation of virtual particle-antiparticle pairs at the event horizon as observed by the accelerating observer in its accelerated frame of reference. The only thing that really seems to be fundamental to the explanation is the observer itself.

There are a number of interesting aspects of the holographic principle that are worth exploring. The first is the idea of quantum entanglement, which is inherent in the idea of a quantized bit of information or qubit. Quantum entanglement allows the qubits to be defined in a rotationally invariant way. This phenomena is much like the way quantum theory defines spin ½ particles in terms of a 2x2 SU(2) matrix. The SU(2) matrix gives a representation of rotational symmetry on the surface of a sphere, but its two eigenvalues also define spin up and spin down states. These two spin states give a representation of information in a binary code, like a switch that is either on or off. The spin up and spin down states are like vectors that point up or down, but when these spin states are entangled, the vector can point in any direction, and so rotational symmetry is preserved. With the holographic principle, the n qubits of information encoded on a spherically symmetric holographic screen can be defined by the n eigenvalues of an nxn SU(2) matrix.

This tells us that the n qubits of information encoded on a holographic screen are fundamentally entangled with each other. A holographic world defined by the qubits of information encoded on a holographic screen is fundamentally a world where everything is connected to everything else at the level of quantum entanglement. A holographic world is inherently holistically connected.

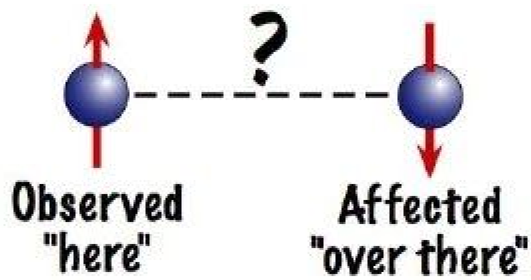
The holographic principle also resolves all the apparent paradoxes of quantum theory that arise when multiple observers are assumed to exist in the same observable world. The holographic principle fundamentally says that every observer has its own holographic world defined on its own holographic screen that arises as an event horizon in the observer's accelerated frame of reference. Paradoxes like the Schrodinger cat paradox or the Wigner friend paradox only arise when we assume that multiple observers exist in and observe the same observable world, but that assumption is not consistent with the holographic principle. The holographic principle requires a new paradigm, which is best summed up by the idea of one-world-per-observer. Every observer observes its own holographic world as defined on its own observer-dependent holographic screen and so there can be no paradox of multiple observers observing the same observable world.

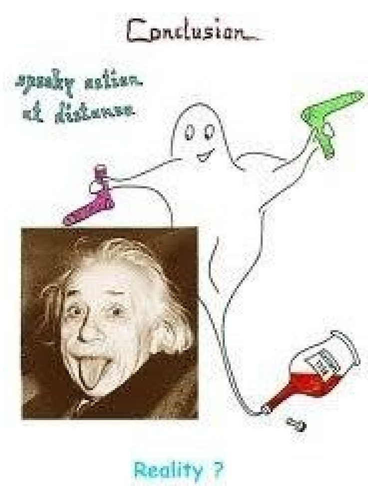
What are we to make of our impression that multiple observers do exist in the same observable world? The answer is information sharing among different observers. Every observer's world is defined on its own holographic screen that arises as an event horizon or a bounding surface of space in the observer's accelerated frame of reference. Those bounding surfaces of space can overlap in the sense of a Venn diagram and share information, like the kind of information sharing we see in an interactive network of computer screens, like the internet. This means that different observers located at different points of view in space can share a consensual reality to the extent that their respective holographic screens overlap and share information, even though each observer observes its own holographic world defined on its own holographic screen.



Overlapping Bounding Surfaces of Space Create the Appearance of a Consensual Reality

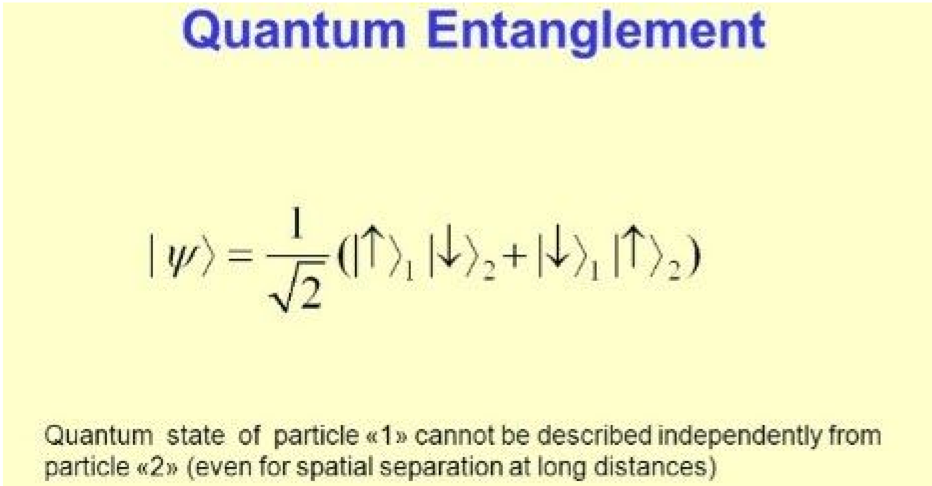
The holographic principle also resolves the apparent paradoxes of quantum entanglement. When two entangled spin ½ particles appear to separate in space, observation of the spin state of one particle instantaneously determines the spin state of the other particle, no matter how far apart the particles have separated. Einstein was so freaked-out by this phenomena he called it spooky action at a distance, and used it as an argument for why quantum theory must be wrong.



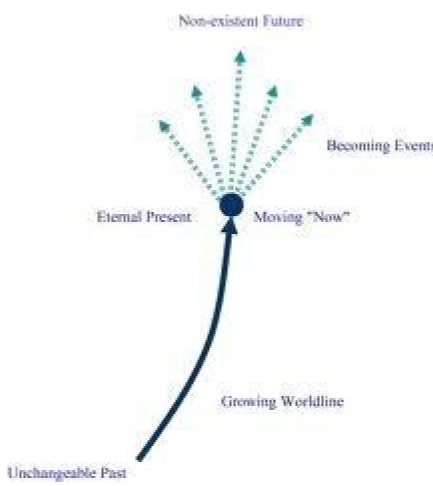


Spooky Action at a Distance

This conclusion seems inevitable when we look at the wave function for entangled particles.



As soon as we measure the spin state of the first particle, we collapse the wave function and determine the spin state of the second particle, no matter how far apart the particles have separated in space, or so it would seem. The resolution of this apparent paradox is holographic projection. The measurement of the position of a particle in three dimensional space is only a holographic illusion that results from holographic projection. All the qubits of information for both particles are actually defined on a holographic screen, and those qubits are inherently entangled. Measurement of a particle's position in three dimensional space is only a holographic projection of a form of information projected like an image from the observer's holographic screen to the observer's central point of view. There is no paradox because nothing really separated in space. Only a holographic illusion of a particle appeared to separate in space.



Decision Point

As a final topic, it's worth pointing out the quantum state as formulated as a sum over all possible paths in an information configuration space implies that every point on some path is a possible decision point about what to observe at that point and which path to follow. Each such decision about what to observe and which path to follow is a choice. The laws of physics only determine the quantum probability of those choices when choices are made in an unbiased way. When bias arises in the way choices are made, the laws of physics lose their predictability and all bets are off. The way we make our choices about what we will observe in the world and which path we will follow through the world can only arise from the way we focus our attention on our choices, and the focus of our attention is an inherent aspect of our consciousness.

There is no way we can discuss the nature of the world we appear to live in without discussing the nature of our consciousness. The holographic principle has something rather dramatic to say about the nature of our consciousness. Each of us as a presence of consciousness is present at the center of our own holographic world. Each of us perceives our own holographic world as defined on our own holographic screen. An enormous implication of this state of affairs has to do with how the world we perceive is created. An even bigger implication has to do with the source of our consciousness. We don't just want to understand how the world is created, but also where our consciousness comes from. It turns out the answer for both questions is the same. The source of our consciousness that perceives the world is also what creates the world we perceive. These two aspects of the world must arise together. There cannot be a perceivable world unless there is also a perceiver of that perceivable world. Both perceiver and perceived arise from the same source. The irony is that source is not something perceivable. That nothingness is called the void.

Creation of a perceivable physical universe can be understood in terms of the potentiality of the void to create a universe while it also gives rise to a presence of consciousness that perceives that universe. This creation process can be described in terms of an observer in an accelerated frame of reference. The mystery of creation is in how the observer arises as a focal point of perceiving consciousness from the void. If we understand the void as the potentiality for creation, the focal point of consciousness of the observer is a separated fragment of that potentiality, just as a drop of water in a raindrop is a separated fragment of the ocean. The other way to say this is the void is a solid block of being, while the focal point of the observer is a separated fragment of individual being. The critical thing to recognize is the nature of that being is the nature of consciousness. The void is a solid block of undivided being, while the focal point of consciousness of the observer is a separated fragment of individual being. The void is one in the sense of undivided being. The void is infinite in the sense of unlimited being. The void is nothing perceivable in the sense of the nothingness of being. The void is the pure potentiality to create perceivable things, but is also the potentiality to become separated into the individual being of the observer of those perceivable things. In-and-of-itself, the void is nothing perceivable since it is the pure potentiality to create and perceive all the perceivable things in a physical universe.

What modern physics has discovered is that the only way this creation process can go forward so that we end up with a physical universe that is governed by the laws of physics, including Einstein's field equations for the space-time metric, which is the law of gravity, and the usual quantum fields of the standard model of particle physics, which include the electromagnetic and nuclear forces, is along the lines of the holographic principle. What is not usually recognized about the holographic principle is that inherent in this principle is both the concept of information and the concept of the flow of energy. All perceivable things are forms of information that arise from the quantized bits of information or qubits encoded on a holographic screen, which is fundamentally understood as an event horizon that arises in an observer's accelerated frame of reference. The flow of energy inherent in the energy of motion of these forms of information is also inherent in the energy of that accelerated frame of reference.

Thermodynamics connects the information encoded on a holographic screen to the flow of energy that gives forms of information their energy of motion. This is best understood in Ted Jacobson's derivation of Einstein's field equations for the space-time metric from the holographic principle and thermodynamics. The holographic principle is formulated in terms of the area law that says the number of qubits encoded on a holographic screen, which is an event horizon that arises in the observer's accelerated frame of reference, is proportional to the surface area of that event horizon. The thermodynamic energy of that event horizon is understood in terms of the Unruh temperature, which is the temperature of thermal radiation the observer observes as emitted from the event horizon that arises in the observer's accelerated frame of reference. The Unruh temperature is proportional to the observer's acceleration. Using these two simple relationships and the purely statistical laws of thermodynamics, Jacobson was then able to derive Einstein's field equations. If the ideas of supersymmetry and extra compactified dimensions of space are applied to Einstein's field equations, we then end up with something that looks alot like 11-dimensional supergravity, which is a low energy limit of M-theory, and we know that M-theory is a holographic theory. M-theory, like string theory, can be understood in terms of non-commutative geometry, which gives a natural explanation for how space-time geometry is quantized. Even fractal geometries can be understood in terms of non-commutative geometry. Fractal geometries express conformal symmetry, which is basically the idea of self-similarity at all distance scales. A fractal looks the same at all distance scales. String theory is a conformal field theory, and expresses conformal symmetry. Conformal symmetry is inherently a symmetry of objects appearing self-similar at different length scales, which is an inherent aspect of a holographic world. This tells us that fundamentally, the creation of the perceivable physical universe from the void is a holographic creation, and that the observer that perceives that physical universe must also be a part of that holographic creation.

The key idea is that to have the creation of a physical universe that is governed by the laws of physics, we have to start with an observer in an accelerated frame of reference. That is how an event horizon arises that acts as the observer's holographic screen that encodes all the qubits of information that characterize all the perceivable forms of information in the observer's world. The flow of energy through the observer's world that is inherent in the motion of all those forms of information is also inherent in the energy of the observer's accelerated frame of reference, which is characterized by the Unruh temperature of the observer's event horizon. The observer itself is only a separated fragment of the potentiality of the void, in the sense that the observer's individual being is a separated fragment of the undivided being of the void, just as a point of view in an empty space is only a fragment of the totality of that empty space. The observer's acceleration, which is necessary both to create a holographic world in the sense of encoding qubits of information on the observer's event horizon and to energize that holographic world in the sense of thermodynamics, also arises from the potentiality of the void. Once we understand the true nature of being is the nature of consciousness, then the observer's individual being as a focal point of perceiving consciousness is understood to come into being from the primordial undivided being of the void. The potentiality of the void is what allows the individual being of the observer to come into being, just as it allows the energy of the observer's accelerated frame of reference to come into being. In the sense of thermodynamics, that's all creation really is. In the language of Advaita Vedanta, the potentiality of the void is Brahman and the consciousness of the observer is Atman, and all that separates them is an observation limiting bounding surface of space acting as a holographic screen that projects all images of the observer's holographic world.

Atman-Brahman

Scientific References

Tom Banks (2018): Why the Cosmological Constant is a Boundary Condition. arXiv:1811.00130
Raphael Bousso (2002): The Holographic Principle. arXiv:hep-th/0203101
Amanda Gefter (2014): Trespassing on Einstein's Lawn (Random House)
Amanda Gefter (2012): Cosmic Solipsism. FQXi Essay
Brian Greene (2000): The Elegant Universe (Vintage Books)
Gerard 't Hooft (2000): The Holographic Principle. arXiv:hep-th/0003004
Ted Jacobson (1995): Thermodynamics of Space-time. arXiv:gr-qc/9504004
J Madore (1999): Non-commutative Geometry for Pedestrians. arXiv:gr-qc/9906059
Roger Penrose (2005): The Road to Reality (Alfred A Knopf)
Lee Smolin (2001): Three Roads to Quantum Gravity (Basic Books)
Leonard Susskind (2008): The Black Hole War (Little, Brown and Company)
Leonard Susskind (1994): The World as a Hologram. arXiv:hep-th/9409089
A. Zee (2003): Quantum Field Theory in a Nutshell (Princeton University Press)