Article

The Principle of Equivalence Really Is Fundamental

James Kowall*

Abstract

The principle of equivalence is the only logical starting point if we want to correlate modern science with spirituality. The equivalence principle specifically refers to a frame of reference, or a coordinate system attached to an observer. Mach's principle tells us that all observations occur in an observer's frame of reference. There is democracy in the relativity of all possible observers, but there is also the freedom of any observer to enter into any possible frame of reference. This freedom is essential to how we understand the nature of observations in quantum theory.

Key Words: Principle of equivalence, frame of reference, observer, consciousness.

Only the onlooker is real, call him Self or Atman.
That which makes you think that you are a human is not human. It is a dimensionless point of consciousness, a conscious nothing. All you can say about yourself is 'I am'.
Nisargadatta Maharaj

We want to correlate modern science with spirituality. I take such a correlation of science with spirituality to be the stated purpose of Scientific God Journal. The only question is how do we proceed in such a task? We have to start somewhere. Whatever assumptions we make will have a profound effect on the outcome of the task.

My basic argument is that the principle of equivalence is the only logical starting point. By the principle of equivalence, I specifically refer to a frame of reference, or to a coordinate system that is attached to an observer. Whatever observations the observer happens to make in that frame of reference, those observations are always relative to the observations made by any other observer in any other frame of reference. Those observations can differ since the two frames of reference can appear to move relative to each other with some kind of relative motion.

Relative theory only has a few fundamental postulates. One postulate is the invariance of the speed of light for all observers, no matter how the observers appear to move relative to each other. Another postulate is the principle of equivalence, which basically says there is a democracy of observations. The observations of any observer as they appear in any frame of reference are as valid as the observations of any other observer in any other frame of reference.

This postulate is fundamentally based on Mach's principle, which simply says there is no such thing as an absolute frame of reference for observations. All observations occur in a frame of reference and are always relative to whatever observations can be made in any other possible frame of reference. This idea is so fundamental that it is worth stating again.

* Correspondence: James Kowall, MD, PhD, Independent Researcher. letranger0101@gmail.com

There is no such thing as an absolute frame of reference for observations.

In the sense of spirituality, whatever the Absolute is, it is not a frame of reference for observations. Only an observer can enter into a frame of reference and make observations, but that frame of reference is always relative to all other possible frames of reference and the observations made by all other observers.

Relativity theory is about the nature of space-time geometries that characterize any possible world. Every space-time geometry is characterized by a coordinate system that localizes points in space and instants in time in some world. When we discuss the one-world-per-observer paradigm of modern cosmology, we'll see that the coordinate system characterizing any possible world is always attached to an observer at the central point of view of that world. An observer's frame of reference defines a coordinate system that localizes points in space and instants in time in the observer's world, but only in that particular observer's world.

In relativity theory, the observer's frame of reference is also called a worldline. The worldline is a path through space and time. Relativity theory tells us that the worldline is a path through space and time followed by an observer, and that the observer is always present at the central point of view of the coordinate system that characterizes that space-time geometry. The observer follows a path through space and time that is at the central point of view of that coordinate system. That space-time geometry is characteristic of the observer's frame of reference.

The principle of equivalence states every force is equivalent to the accelerated frame of reference of an observer. The only reason different observers observe different forces is because they enter to differing frames of reference that move relative to each other with accelerated motion. There really is no such thing as a force, only the differing accelerated frames of reference of observers.

The principle of equivalence tells us that fundamentally all observations have a geometrical basis. The way this occurs is that a coordinate system is always attached to an observer in a frame of reference. When we speak about gravity, we only speak of the 3+1 extended dimensions of space-time. The Kaluza-Klein mechanism tells us that when we speak about the electromagnetic, strong and weak forces, we also speak of an extra six compactified dimensions of space-time. The six extra compactified dimensions can always be understood in the sense of a non-commutative geometry, and so the idea of curling up extra dimensions into a manifold is really only for the purpose of visualization.

The geometrical nature of all observations tells us there is really only one invariant measure of length in the geometry, called the proper time. The action principle and the principle of least action follow directly from the only invariant measure of length in the geometry. Quantum theory can be understood in the sense of summing over all possible paths in the geometry and weighting each path with a probability factor that we call the wave function. The fact that the wave function takes the U(1) invariant form of $\psi=e^{i\theta}$, where the phase angle $\theta=S/\hbar$ is given in terms of the action S, which in turn is given in terms of the geometrical length of any possible path in the geometry, only tells us that quantum theory is also a geometrical theory. Quantum theory simply allows for observations that deviate from the classical path of least action.

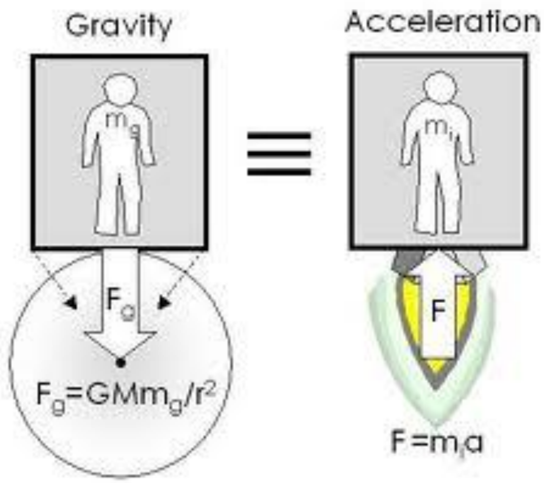
The geometrical nature of observations has significant implications, including the very strange holographic principle [2]. This principle tells us the observation of anything in space reduces down to how bits of information are encoded on the bounding surface of that space. In relativity theory we call such a bounding surface of space an event horizon, which always limits an observer's observations in space. The horizon is as far out in space as an observer at the central point of view can see things in space due to the limitation of the speed of light. The holographic principle tells us that even elementary particles reduce down to bits of information encoded on a bounding surface of space. The holographic principle is best understood in terms of non-commutative geometry, as this unifies relativity theory with quantum theory.

In relativity theory the nature of energy is understood in terms of the geometrical length of any possible path in the geometry. At a fundamental level, kinetic energy arises with all motion due to time dilation, while potential energy only arises in an accelerated frame of reference. This is best illustrated with a simple example.

Imagine a spaceship that accelerates through empty space with an acceleration rate $a=g$. A clock is placed in the front of the spaceship and an identical clock in the back of the spaceship, separated by a distance x. The clock in the front of the spaceship emits a flash of light every $\Delta\tau$ seconds. An observer at the back of the spaceship measures the arrival of each flash of light, and compares the time interval Δt between the arrival of each flash with the time interval displayed on the clock in the back of the spaceship, which is $\Delta\tau$ since the clocks are identical. From the perspective of the observer in the back of the spaceship, each flash of light appears to arrive early, since the spaceship accelerates forward while the flash of light travels at the speed of light from the front clock to the back clock, and so the front clock appears to run fast.

The easiest way to calculate how much the front clock appears to run fast is to use the Doppler effect, $f=f_0(1+v/c)/(1-v^2/c^2)^{1/2}$, which relates the frequency of received light waves, f, to the emitted frequency, f_0, and where v is the relative velocity of the receiver of the waves towards the source of the waves. In the time it takes the light waves to travel from the source to the receiver, the spaceship has accelerated forward in velocity by $v=gx/c$, and the receiver has gained this velocity with respect to the source. Ignoring relativistic effects, the frequency of the received light waves is faster than the emitted light waves as $f=f_0(1+gx/c^2)$. This frequency is given in terms of the time intervals as $f=1/\Delta t$ and $f_0=1/\Delta\tau$.

The principle of equivalence tells us there is no way to distinguish the effects of gravity from an accelerated frame of reference. The acceleration due to gravity at the surface of the earth is $g=GM/R^2$. If we have a clock on the surface of the earth and an identical clock at a height x above the surface of the earth, the clock at the higher elevation appears to run faster by an amount $\Delta t=\Delta\tau/(1+gx/c^2)$. The clock at the higher elevation appears to run faster due to its equivalence to a clock in an accelerated frame of reference [3].



How do we discover the action principle from this effect? Einstein tells us to look at the proper time interval, which is the amount of ordinary time that passes in a frame of reference that is at rest with respect to a particle. Einstein tells us the particle follows a geometrical path through space-time that maximizes proper time relative to all nearby paths. That path is like the shortest distance between two points in a curved space-time geometry. If that particle moves in the earth's gravitational field at a height x above the surface of the earth, the time interval measured as observed at the earth's surface is $\Delta t=\Delta\tau/(1+gx/c^2)$. If that particle moves with a velocity v with respect to the observer at the earth's surface, we also must include the effects of time dilation, $\Delta t=\Delta\tau/(1-v^2/c^2)^{1/2}$. Putting these two effects together allows us to write the observed time interval as $\Delta t=\Delta\tau/[(1+gx/c^2)(1-v^2/c^2)^{1/2}]$.

In the non-relativistic limit we can approximate $\Delta\tau=\Delta t(1-\frac{1}{2}v^2/c^2+gx/c^2+\ldots)$. If we define the particle's action in terms of its mass and proper time as $\Delta S=-mc^2\Delta\tau$, we then find that $\Delta S=\Delta t(\frac{1}{2}mv^2-mc^2-mgx)=(KE-PE)\Delta t$. The potential energy includes the mass energy and the gravitational potential energy as $PE=mc^2+mgx$, while $KE=\frac{1}{2}mv^2$. Einstein tells us the particle will follow a path through space-time that maximizes the proper time interval, or minimizes the action. Kinetic energy arises from time dilation, and potential energy arises from the effects of an accelerated frame of reference, which we call a force. Both kinds of energy are geometrical in nature. Even the $1/R^2$ force law, as in $g=GM/R^2$, is geometrical in nature, and arises from the amount of particle flux that crosses the surface area of a sphere.

Relativity theory tells us that observations of energy are purely geometrical in nature, and only arise with the relative motion that relates one frame of reference to another frame of reference. With the holographic principle, we'll see that the quantized bits of information that define the observation of anything an observer can observe only arise in the observer's accelerated frame of reference, since that is how the observer's event horizon arises.

It only makes sense to speak of these observations if an observer is attached to a coordinate system in a particular frame of reference. However the observer's coordinate system is defined, and however many independent dimensions it has, that coordinate system is always attached to an observer in a frame of reference.

It makes absolutely no sense to speak of a coordinate system without speaking of an observer and a frame of reference. We can always think of the observer as at the origin or the central point of view of that coordinate system. Every frame of reference has an observer at the central point of view of its own coordinate system. There is no such thing as an absolute coordinate system.

This conclusion bears repeating:

Every frame of reference has an observer at the origin, or at the central point of view, of its own coordinate system.

That coordinate system belongs to that particular observer, just as the observer's own observations belong to that observer. The observer is the owner of its own coordinate system and its own observations. That coordinate system is always attached to that particular observer in that particular frame of reference.

In addition to the idea of the democracy of all possible frames of reference, there is also the idea of freedom. The observer is free to enter into any possible frame of reference. When we say there is no such thing as an absolute coordinate system, we are giving the observer the freedom to enter into any possible frame of reference. This freedom is a key idea in the unification of quantum theory with relativity theory, as we'll see when we discuss the holographic principle.

The key geometrical idea of the holographic principle is that a bounding surface of space always arises for an observer that enters into an accelerated frame of reference. We call that bounding surface of space an event horizon. In a non-commutative geometry, the position coordinates that localize points on the bounding surface are represented by non-commuting variables, and so they have inherent uncertainty. Like any other non-commuting variable in quantum theory, there is inherent uncertainty when we measure a position coordinate on a bounding surface of space. Unlike measurements of the position and momentum of a particle in ordinary quantum theory, as described by the usual uncertainty principle, a non-commutative geometry describes uncertainty in the measurements of the position coordinates of space itself. This uncertainty is the reason a bounding surface acts as a holographic screen that encodes information in a pixelated way, with one bit of information encoded per pixel on the screen.

It helps to recapitulate these ideas:

- A bounding surface of space always arises for any observer that enters into an accelerated frame of reference.
- The position coordinates localizing points on a bounding surface of space are represented by non-commuting variables and their measurement has inherent uncertainty.
- This uncertainty is the reason a bounding surface acts as a holographic screen that encodes information in a pixelated way, with one bit of information encoded per pixel.

This brings us back to the reason the principle of equivalence is fundamental. The observer must enter into an accelerated frame of reference for the process to even begin. If the observer does not enter into an accelerated frame of reference, then there is no process.

These fundamental concepts raise an important question. Who or what is the observer? This is the only entry point that allows us to correlate modern science with spirituality. The only way to scientifically understand spirituality is in terms of consciousness. This is where we have to part company with most of science, like the field of neuroscience, which attempts to attribute the origin of consciousness to some kind of emergent mechanism that occurs in a biological brain.

Unfortunately for neuroscience, as Roger Penrose [4] has brilliantly pointed out, such scientific speculation is really not science at all, but only pseudoscience. The incompleteness theorems prove beyond a shadow of a doubt that there is no computational mechanism that allows consciousness to emerge from a biological brain that performs consistent computations. It is logically impossible for any kind of a consistent computational mechanism, whether biological or not, to generate the consciousness that knows about the consistency of the mechanism.

What is the alternative to the biological explanation? The answer is readily apparent from the principle of equivalence. The observer is the consciousness present at the origin, or at the central point of view, of the coordinate system that is attached to the observer and characterizes the observer's frame of reference. The observer is nothing more than the consciousness present at the central point of view of its coordinate system. This bears repeating.

The observer is nothing more than the consciousness present at the central point of view of a coordinate system that characterizes a frame of reference.

There is an important aspect of the principle of equivalence that we have not yet explored. If the observer is only a point of consciousness present at the central point of view of a coordinate system that characterizes a frame of reference, how can different frames of reference appear to move relative to each other? What actually moves? There is no way to answer this question without the holographic principle, which tells us that everything observed in a frame of reference, from elementary particles to macroscopic bodies, reduce down to bits of information encoded on a bounding surface of space. The bounding surface is an event horizon that arises because the observer is in an accelerated frame of reference. The bounding surface acts as a holographic screen that projects images of things to the central point of view of the observer. The key question is about the nature of these projected images.

Images of things are only forms of information defined on the holographic screen. The forms appear as three dimensional objects in space, but are defined by bits of information encoded on the two dimensional bounding surface of that space. The bits of information arise because the position coordinates on the bounding surface have inherent uncertainty. The coordinates become smeared out into pixels that encode information for everything observed in that bounded space.

This is even the case for elementary particles. The apparent motion of anything in the space-time geometry of an observer's frame of reference only appears as images of that thing are projected from a holographic screen to the observer's central point of view and as those images are animated over a sequence of events like the frames of a movie. Due to the nature of holography, there really is no such thing as a point particle, since it is impossible to define points in space. Only pixels encoding bits of information on a holographic screen can be defined. This is the fundamental way in which space-time geometry is quantized.

As Leonard Susskind [2] expresses it: "The objective reality of points of space and instants of time is on its way out, going the way of simultaneity, determinism, and the dodo. Quantum gravity describes a much more subjective reality than we ever imagined... It is a reality that in many ways is like the ghostly three-dimensional illusion cast by a hologram."

Points of space and instants of time have no objective reality because points and instants are only defined in terms of the way bits of information are encoded on a holographic screen. There is inherent uncertainty in that encoding process, and the screen only arises in the frame of reference of the observer of that screen.

Why is the holographic screen a two dimensional bounding surface of space? Why not a three dimensional bounding surface, like a hyper-sphere? The answer is we live in a world that only has three extended dimensions of space along with the concept of a time-line. The time-line only consists of a sequence of events, like a sequence of screen outputs from a computer screen. Fundamentally, this sequence of events can only arise on an observer's worldline. Although the Kaluza-Klein mechanism may apply to our world, with extra compactified dimensions of space, manifestly there are only three extended dimensions of space.

As an observer enters into an accelerated frame of reference and follows a worldline through the 3+1 extended dimensions of space and time, a bounding surface of space arises that surrounds the observer at the central point of view. The bounding surface is an event horizon. That bounding surface is two dimensional. If that surface acts as a holographic screen, then each event on the observer's worldline is just like a screen output from a computer screen.

The reason we are able to relate the relative motion of one frame of reference to another frame of reference is because every observer is surrounded by a central form of information, or a central image. We call such a central form of information a body. Every observer has an animated body in the animation of images arising from the holographic screen that surrounds the observer at the central point of view, and those objects in space can appear to move relative to each other.

This brings up another important aspect of the holographic principle. Every observer is surrounded by a bounding surface of space that encodes all the bits of information for everything observed within that bounded space, but different bounding surfaces of space can overlap and share information with each other through a phenomena we call quantum entanglement. This is the fundamental reason we are able to share a consensual reality. The observer is nothing more than the consciousness present at the center of that bounding surface of space, but different observers can share a consensual reality because their holographic screens can overlap with each other in the sense of a Venn diagram and share information.

The holographic principle tells us the observer is the consciousness present at the central point of view of a bounding surface of space that arises because the observer is in an accelerated frame of reference. Non-commutative geometries unify relativity theory with quantum theory since the position coordinates on the bounding surface are represented by non-commuting variables, which explains how quantized bits of information are encoded on the bounding surface.

A number of puzzles about the nature of consciousness arise in quantum theory. Quantum theory is based on the idea of a quantum state of potentiality, which is very much like a menu of possibilities from which one can choose. A choice is an observational event, which is called a quantum state reduction. With each choice, some observable thing is actually observed. The observable thing observed with that choice is called an observable of the quantum state. The quantum state is only like a menu of possibilities from which one can choose and observe things. There is a hidden and usually unrecognized assumption in quantum theory that before any choice is made or any observation occurs, the observer must exist.

In much the same way, relativity theory also assumes the independent existence of the observer. Relativity theory is based on the principle of equivalence, which postulates that all observations are relative to each other and only arise in the frame of reference of an observer. Before the observer enters into any possible frame of reference, the observer must exist. The only way quantum theory can be unified with relativity theory is if the observer has an independent existence. The observer must exist before the observer enters into any possible frame of reference, before any choice is made, and before any observation occurs.

In quantum theory, the observable values of any observable thing arise from a quantum state of potentiality. Before the observation of anything occurs, the observable thing only exists in the sense of a quantum state of potentiality. The quantum state is only a sum over all possible ways something can be observed, and there is always uncertainty in the way choices are made that allow for the observation of anything to occur. That uncertainty is inherent in the choices made as the observation of anything occurs. An observable thing does not have its own independent objective existence, but always depends on the choices made with the observation of the thing. Only the observer can have an independent existence.

This puzzle about the nature of observation as formulated in quantum theory only makes sense in the context of the one-world-per-observer paradigm, which is the only natural way quantum theory can be unified with relativity theory. A quantum state of potentiality that characterizes an observer's world can only arise in the frame of reference that defines the observer's world.

Whatever the observer observes in its world depends on its frame of reference and the choices made by the observer with any observational event. This does not rule out the possibility of a consensual reality shared by many observers if their differing frames of reference are able to share information with each other.

The inevitable conclusion of the one-world-per-observer paradigm is that the observer's world does not have an independent objective existence. Everything observed in the observer's world is observer-dependent. Everything that appears to happen in the observer's world depends on the observer's frame of reference and the choices made with any observational event.

Without the independent existence of the observer, the observer's world cannot exist. The observer's world cannot have an independent objective existence, but only an apparent subjective existence that depends on the observer's existence.

In reality, only the observer is real and has an independent existence. Everything that appears to exist in the observer's world depends on the observer's frame of reference. Even when observed, the observable things do not really exist with an independent objective existence, but only have an apparent subjective existence that depends on the observer's existence.

In this sense, observable things are unreal since they only appear to exist for an observer. If the observer does not exist, those things do not exist. In reality, only the observer is real with an independent existence, but the observer is not an observable thing that it can observe in its world. The observer is not-a-thing that can appear in its world. The observer can only be understood as the nature of consciousness, which is not-a-thing in the sense that it is not an observable thing that appears in its world. Only the observer can observe the observable things that appear in its world, but the observer itself is not an observable thing.

As Roger Penrose [4] points out, this is the inevitable conclusion of the Gödel incompleteness theorems if the observable things are described by a consistent set of computational rules, as is the case in quantum theory. The consciousness that knows about the consistency of the rules cannot itself emerge from the rules. Consciousness is 'outside' the rules.

The one-world-per-observer paradigm tells us the observer is nothing more than the consciousness present at the center of its world. When we speak of "the eye of the beholder", we are really only speaking about the nature of consciousness present at the center of its world. The difficulty incorporating this idea into science is in understanding the nature of that nothingness.

What is consciousness? The consciousness present at the central point of view of a coordinate system that characterizes a frame of reference is the observer that makes observations in that frame of reference. Since the observer is nothing more than a point of consciousness, we really cannot say what the observer is.

As Nisargadatta says, "all you can say about yourself is *I am*." When we say "the eye is the window to the soul" or we speak of "the mind's eye", we only refer to the observer. As a point of consciousness present at the central point of view of a coordinate system that characterizes a frame of reference, there is really nothing else to say about it, except to say *it is*. The sense of being present can only arise from the observer, and so we can truly say that the observer is *being itself*. In the same sense, the only true knowledge the observer can ever know about itself is that *it exists*. This conclusion is the essence of solipsism.

Only the observer has a sense of being present. Only the observer can enter into a frame of reference and make observations in its own frame of reference. The only true thing we can say about the observer in a scientific sense is that it is the consciousness present at the central point of view of a coordinate system that characterizes a particular frame of reference.

This is the only consistent way to interpret the principle of equivalence. This is the ground of being that we must stand upon if we are to relate science to spirituality. This is the true nature of our reality; the reality of being an observer of whatever we happen to observe in any frame of reference into which we happen to enter.

The physical and mental reality we observe in some sense is unreal; no more real than observations we make of a virtual reality world; no more real than the animated images we observe as projected to us from a holographic screen that arises because we've entered into an accelerated frame of reference; no more real than the reflected shadows we perceive that we cast upon the wall of a cave.

As the Bhagavad-Gita puts it:

The unreal has no being.
The real never ceases to be.

References

1. Nisargadatta Maharaj (1973) *I Am That*. (The Acorn Press, Durham).
2. Leonard Susskind (2008) *The Black Hole War*. (Little, Brown and Company).
3. Principle of equivalence image from mysearch.org
4. Roger Penrose (1997) *The Large, the Small and the Human Mind*. (Cambridge University Press).
5. *The Bhagavad-Gita*. (1909) Sir Edwin Arnold trans. (The Harvard Classics).