THE STUBBED T.O.E.

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A Unified description of all known forces (electromagnetism, the strong and weak nuclear forces, and gravity) will be a Theory Of Everything (T.O.E.). It doesn't exist yet, but many physicists believe it *can* be created.... Such a theory will require that all forces have certain things in common. For example, in Quantum Mechanics the notion of "exchange particles" is used to explain how each force works: Electromagnetism features particles with electric (and maybe also magnetic) charge which exchange photons; the strong nuclear force exchanges pions between protons and neutrons, yet this is a side-effect of the exchange of gluons between the quarks that combine to form pions, protons and neutrons; and the weak nuclear force employs exchange particles known as W and Z bosons. The gravitational force will be described with exchange particles called gravitons.

But our description of gravitation differs from the other forces at one very important point: Each of the four forces includes the concept of "potential energy", but the definition of that concept is different for gravitation! When particles interact through any force, some energy may be stored in a form called "potential" -- or some energy may be released from storage. In three of the forces, potential energy takes the form of mass; in gravitation, the form is distance-and-gravity-gradient. Newton proposed this form because he could make it work consistently -- but Newton never knew that $\mathbf{E}=\mathbf{mc}^2$! I submit that as long as physicists stubbornly stick in the rut of Newton's proposal/assumption, any effort to Unify Gravitation into a Theory Of Everything will be stubbed. The background concept of potential energy must be Unified first....

Complicating the issue enormously are some of the very shortcuts that modern physicists use to make their calculations easier. Relativity allows any given point to become the center of a "reference frame", a region in which various events can be described in a simple way. Furthermore, physicists get to work with the powerful idea that certain aspects of any locality can be treated as if they were identical to equivalent aspects of any other locality.

1. Take, for example, the masses of a proton and a neutron, and add them. Then "fuse" the particles to form a deuteron -- and measure its mass. We find that the deuteron's mass is less than the sum of the masses of its constituent particles. The difference turned into energy that escaped when the deuteron formed; this is a simple example in which potential energy (some of the original mass) is released from storage (during fusion) and becomes "freed" energy. Knowing this information only, it *might* seem reasonable to conclude that, within the deuteron, the proton and neutron have each lost some mass, so that their sum equals the observed deuteron mass...but read on!

2. How *do* physicists describe the masses of the proton and neutron, when they talk about what is happening inside the deuteron? Well, before they start, *they change reference frames!* In other words, what was just described in the previous paragraph, about differences in measured masses, is ignored. That data is considered to have been gathered in the environs, or reference frame, of a quality laboratory, equipped to measure masses of protons, neutrons, and deuterons. But to describe the workings of a deuteron, physicists mentally dive right into the midst of that object, and use a frame of reference specific to its innards alone. In *this* reference frame, the masses of the proton and neutron are considered to be exactly the same as what they were, when separated in the quality-laboratory reference frame. The reason why physicists do a frame-switch is partly because General Relativtiy allows it (even encourages it), and partly because it makes the mathematical descriptions vastly less complicated. The results of those calculations have proven to be very accurate, so frame-hopping will continue.

3. The problem that I wish to point out is twofold. First, physicists change reference frames so casually these days that they seldom bother any more to tell you when they are doing it. Everything is handled locally, using a plethora of local reference frames! Which leads to the second item: Each one of those localities constitutes a "tree" in the "forest" of Reality. A Theory of Everything will be a description of the whole forest! *How* are physicists *ever* going to create a T.O.E. if they never stay in one reference frame long enough to describe the big picture? Frame-hopping just stubs their efforts!

Debates now seem inevitable, concerning what reference frame to use. I shall suggest that the ideal frame has its origin at infinite distance from any ordinary "local" reference frame. Such an origin would by definition be common to all local reference frames. Certain other properties of that "Distant Reference Frame", or DRF, can be somewhat arbitrary. For example, there will be times when we want to examine something locally, in which case one object at that locality might be assumed to possess zero velocity. When describing that object from the viewpoint of the DRF, we can still assign it a velocity of zero. Only when objects in two different local frames need to be described might we worry about what velocity each has, in relation to the DRF.

Finally, one other reason for employing a DRF has to do with electromagnetic and gravitational fields: Both are described as being influential out to infinite distance. The DRF is located outside of the influence of any electromagnetic or gravitational fields, of every local reference frame! I hope to show that this will be a very important point, when using a DRF as part of the basis for a T.O.E.

Essaying now to re-consider the previously-described scenario of proton plus neutron yields deuteron, I wish to start with the well-known fact that their fusion is a consequence of the Strong Nuclear Force. This is a very short-range force; thus the reference frame of the "quality laboratory" can be thought of as being very "distant" from the effects of the Strong Force. In this sense only (because the laboratory is not outside the range of the electric field of the proton), the reference frame of the lab is roughly equivalent to the proposed infinitely-distant all-purpose DRF. For the moment, recall that in the lab's reference frame -- or DRF -- there is energy that appears when the proton and neutron fuse to form a deuteron, and this energy is equated to the difference in mass between the deuteron and the sum of proton and neutron masses. Next, make the physicists' typical mental switch to the deuteron's reference frame, and recall that here we can treat the proton and neutron as if they have the same masses as when measured separately in the DRF. So how *do* those masses add to equal the observed lesser mass of the deuteron? The answer involves a simple bookkeeping trick known as "negative binding energy":

1. ***B****efore* the two particles fuse, we have “mass of proton” plus “mass of neutron”.

2. *When* fusion occurs, we have those same two things plus “freed energy” plus “negative binding energy”; these two amounts of energy are exactly equal in magnitude.

3. *After* the fusion event is over, we have “mass of proton” plus “mass of neutron” plus “negative binding energy” equals “mass of deuteron”. The “freed energy” has escaped the local system and can be ignored; it is not needed in the description of the deuteron's innards, thanks to the bookkeeping trick.

4. However, it is *only* a trick! It is assumed to be a required trick, thanks to General Relativity. After all, we must be *able* to examine the proton or neutron inside the deuteron, and see it behave no differently from when it is outside the deuteron. Still, required or not, it remains a trick, because the fact is, nobody has ever actually observed any "negative binding energy". This means that while it will forever be a useful trick, it is not necessarily descriptive of a True Aspect of the Universe. Beware! A Theory Of Everything must not be confused with tricks. (Besides, there is an alternative....)

From the viewpoint of the DRF, therefore, how might we describe the innards of the deuteron? All we have to work with are the observations of lessened mass being equal to the freed energy, so why not start with the notion that the mass of the constituent particles really is lessened? This does *not* automatically mean that the behavior of the particles, as described from within a deuteron, must become different than before! The reason I say that is: Nothing is fully isolated! Therefore:

1. In the Distant Reference Frame, we have units of Mass, Space, and

Time which are arbitrarily declared to represent "baseline" values. We know full well *that* these phenomena may differ in different reference frames; exactly *how* they differ depends on the specific different reference frame.

2. As our first example, let's take the "accelerated" situation of a spaceship moving nearly at light-speed relative to the DRF, in accordance with Special Relativity: Mass has increased, one dimension of Space has shrunk, and Time has slowed. Yet *inside* the spaceship (using its interior reference frame), everything looks perfectly normal, and neither Mass nor Space nor Time appear to have changed in the slightest. We need to try to explain this normality from the viewpoint of the DRF.

Begin with two people on the spaceship, playing catch. For them, the ball behaves as if it has normal mass, while viewed from the DRF its mass may be twice that (for example).

Consider this: Viewed from the DRF, *everything* about the two people also has twice as much mass (which we all know is equivalent to energy). Their muscles have twice as much mass, but also doubled is the "energy density" of the chemical reactions in their bodies' cells, that power those muscles. So without any conscious effort, the two people are automatically putting twice as much effort into throwing the doubled-mass ball, back and forth. *Of course* everything seems normal, when we switch from the DRF to the reference frame aboard the spaceship! In terms of fundamental ratios, absolutely nothing has changed between the two reference frames!

Does it not seem obvious that if all relevant ratios between Mass, Energy, Space, and Time remain constant from reference frame to reference frame, then should a *real* change ever occur, it can go utterly unnoticed? It can even be deliberately neglected, which is exactly what General Relativity tells physicists to do, to simplify their math! However, neglecting a real change is one thing; ignoring it as if it wasn't real is another thing altogether...since the accelerated spaceship, relative to one parked in the DRF, *does* have real differences in its Mass, Energy, Space, and Time.

3. As our next example, let's study an ultramassive black hole. One of the properties about such an object is that even though it has superlatively astronomical mass, the force of Gravitation around it still diminishes in accordance with the good old inverse-square law. Meanwhile, the diameter of its "event horizon" (the purely mathematical boundary that we can call the "surface" of a black hole) increases directly with the mass of the black hole. If its mass is doubled, then its horizon's diameter is also doubled. For an ultramassive hole, the diameter of its nonphysical event horizon can be very large, while the strength of its gravitational field, at that horizon, can be relatively weak. Digression into some additional details may be appropriate:

i. Consider the Sun, which has a diameter of about 1.4 million kilometers, or 700,000 km in radius. At what appears to be the surface of the Sun, the force of gravity is about 27 times what it is at the Earth's surface (which is about 6400 km in radius).

ii. If the Sun was replaced by a black hole of exactly the same mass, then its event horizon would be less than 10 km in radius, and the force of gravitation would be quite extreme at that location -- but at 700,000 km from the hole, the force of Gravitation would be practically identical to the Sun's surface-gravity. Remember, in computing gravity for an ordinary object like the Sun, as long as we refer to locations in space outside the volume occupied by the object, then we can pretend that *all* the object's mass is located at a central point -- making the math simpler. And all the mass actually *is* at that central point, when describing a black hole. So, at 700,000 km from either the center of a Sun-mass hole, or from the center of the Sun itself, the gravitational effects of identical masses...are basically identical. Only because a black hole has no physical substance separating us from its central point, can we get close enough to that point to describe awesome gravitational effects.

iii. As you know, if you get far enough away from anything, no matter how massive it is, then the force of its Gravitation that you would experience could be quite small. Meanwhile, however, there is the "gravitational force gradient", or "gravity well", which depends directly on the mass of an object. The simplest way to describe it is in terms of "escape velocity". To escape the gravitational attraction of the Earth, for example, an object must be given a velocity of about 11 km per second. As the object heads directly away from the Earth, it is gravitationally slowed down, but by the time it has slowed to zero velocity, it will be located infinitely far away from the Earth. We might say that by giving the object an initial velocity of 11 km per second, the object can be tossed up onto the "lip" of the Earth's gravity well.

But the Sun is much more massive than the Earth, and has a significantly deeper gravity well, so a higher initial velocity is required, to send something up onto the lip of that well. And a black hole can have a deeper well yet, but now an odd situation enters the description, because the escape velocity for all black holes is the same: light-speed!

Computations begin at the event horizon; it is at that location, some distance from the center of a black hole, that the escape velocity equals light-speed. This definition is about half the reason why Black Hole A, with twice the mass of B, also has an event horizon of twice the diameter of B. (The "starting location" for launching an object-to-escape-from-A simply *must* be farther from the center, than for B.) The rest of the reason derives from the increased size of A's gravity well, of course. Obviously, the farther away at which an object can begin to accelerate toward a given black hole at, say, 1 micron per second per second, the farther away from the hole it will be when it reaches its maximum "terminal velocity", as a result of uninterrupted acceleration. (For most massive bodies, the terminal velocity is the same as the escape velocity, so if this was true for black holes, the terminal velocity would be light-speed -- and there is much more about this to describe later, when we return to the subject of gravitational potential energy.)

Back to the supermasive black hole: It is possible to describe such a huge one that it has an event horizon located so far from its center that the perceived "surface gravity at the event horizon" (remember, there is no actual physical surface) is the same as Earth's surface gravity, while the hole's gravity well is still so deep that to escape, an object starting to move away from that mathematical surface must have a velocity of light-speed. The overall environment is quite different from Earth's, however; General Relativity describes conditions in which, relative to a Distant Reference Frame, time passes very slowly, much like a spaceship moving near light-speed, but here lengths have increased instead of shrunk. Nevertheless, if two people happened to find a way to play catch in this environment, for them everything will still seem normal, thanks to all important ratios having changed in sync. Once again, therefore, physicists can have a relatively easy time describing events in this local reference frame -- but they still *need* to occasionally describe things from a DRF's perspective, for the benefit of a T.O.E.

4. As we finish all that digressing, I hope you realize that there has to be a way to describe the innards of a deuteron, from the perspective of a DRF, such that we *could* work with reduced masses for its constituent proton and neutron, yet their overall behavior will match the results as computed from the perspective of the up-close-and-personal locale.

Brewing up such a description may mean borrowing from General Relativity, to get the idea that within a "Strong Nuclear Force field gradient", the flow of Time may differ from the flow of Time when no such significant force is present. Reiterating, here is a more formal rationale:

i. There *must* be a way to describe the innards of a deuteron from a DRF, so:

ii. If the masses of a deuteron's constituent proton and neutron are viewed as being reduced, then there *must* exist some compensating factor or factors (ratios that stay in sync), which we have to also include in the DRF's perspective.

iii. A notion from Quantum Mechanics, the "wave/particle duality", may now be appropriately applied. Physicists have noted that every particle-like thing seems to have some wave-like properties, and every wave-like thing seems to have some particle-like properties. Equations exist which precisely describe this phenomenon, but the basic ideas behind them are easily explained....

Because a particle's main property is its mass, and a wave's main property is its energy, we can ask, "If mass and energy are equivalent, why not particles and waves?" *Yes*! Mass *can* be associated with wavelength and frequency (a wave's rate of oscillation), and the less mass/energy for any thing, the lower its frequency and the longer its wavelength!

Conventionally, however, physicists associate momentum, not mass, with wavelength and frequency. Yet that issue can be sidestepped by a somewhat unconventional explanation.... Start with a photon: Its *f*requency and *e*nergy-content are associated according to the formula $\mathbf{E} = (\mathbf{f})(\mathbf{h})$, where **h** is Planck's Constant (after the man who created that equation). Next, since we all know that $\mathbf{E} = \mathbf{mc}^2$, a mass should have a frequency according to $\mathbf{mc}^2 = (\mathbf{f})(\mathbf{h})$, or $\mathbf{f} = \mathbf{mc}^2 / \mathbf{h}$. Finally, *w*avelength is associated with *v*elocity and *f*requency according to $\mathbf{w} = \mathbf{v} / \mathbf{f}$. Computing wavelengths for photons is easy, because they all move at the same speed -- but different masses move at different speeds. Yet because There Is No Such Thing As Absolute Rest, all masses definitely do move (if only in terms of molecules jostling inside an object which appears to be at rest). It is now convenient to pick an arbitrary speed, and to assume that all masses being described are moving at that rate. (*M*omentum equals *m*ass times *v*elocity, so if velocity is a constant, comparing momentums can be reduced to comparing masses only.) With that assumption in the background, any mass *can* be directly associated with a wavelength. Then only differences in mass will matter, when examining different objects under the lens of the wave/particle duality.

Different reference frames *can* allow us to describe a single particle with different frame-related masses, so, thanks to the wave/particle duality, we are most conveniently and automatically *also* given differing associated frequencies -- or "synchronized differing relationships with Time" -- for that particle, in each different reference frame!

iv. With such an equivalent consequence of General Relativity's field-gradient stuff coming our way so easily, it may indeed be realistic to borrow things from G.R., to help develop a ratio-synchronized DRF description of events in the innards of a deuteron.

Cop-out time: Having presented a possibly reasonable starting point for such a description, I will not be pursuing all the details here, partly because I am certain it can be done better by others, and partly because I have too much else yet to discuss in this essay (some of which turn out to be a few more details concerning this topic).

Gravitation is the force about which any proposed T.O.E. must most concern itself, in a manner that resolves differences between Quantum Mechanics and General Relativity. Herein I shall be taking the approach that if Q.M. is developed in the right way, then the results of G.R. will naturally appear, and part of that "right way" is to think about working with Q.M. from the perspective of a DRF. As preparation for pursuing Gravitation, then, it may be wise to digress once more: from the topic of the Strong Nuclear Force for a deuteron, to the topic of the Electromagnetic Force for an ordinary average hydrogen atom:

1. From the perspective of the DRF, a lone proton has a certain amount of mass, and a lone electron also has a certain mass. Should the two happen to have a close encounter, an ordinary protium hydrogen atom may be formed, courtesy of an electrical attraction between proton and electron.

2. Since the Electromagnetic Force has infinite range, and has been studied closely for most of two centuries, it is quite easy for us to talk about "electric force field gradients", in which the proton and electron would be located (in each other's gradient, of course), at the beginning of our examination of their interaction.

3. Conventionally, when talking about basic events, we begin a description with stationary particles. Thus, and jumping right to the end of this event, we note that a photon of energy (and sometimes more than one) is released when the atom forms. Where did that energy come from?

4. A couple well-recognized possibilities exist:

Begin, say some, by claiming that prior to the interaction there simply existed some potential for energy to be released, and so naturally it did get released, as the interaction occurred. Furthermore, should someone want to pry apart that newly-formed hydrogen atom, it would be necessary to inject that same amount of energy -- which eventually becomes "potential". In fact, both Gravitation and the Strong Nuclear Force have counterparts to this description, which makes this a powerful idea.

Complete details, however, are lacking about the *form* that potential energy takes, in the preceding description. For the Strong Nuclear Force, potential energy is known to exist in the form of mass, as already described in the deuteron digression -- and for Gravitation, potential energy is traditionally described in accordance with Newton's distance-and-field-gradient method (also as previously mentioned). Which way is true for the

Electromagnetic Force?

Details like this one are important; *Both* ways are known to be workable for Electromagnetism! For proton and electron about to combine into a hydrogen atom, assuming potential energy takes the form of mass, and adding negative binding into the calculations -- it works just fine. For two macroscopic bar magnets separated on a tabletop, but allowed via attraction to impact together, it works fine to assume the potential energy, that became their colliding kinetic energy, originally existed in the form of distance-and-field-gradient. Yet Electromagnetism is *one* force, and supposedly only *one* description for potential energy should ever be needed or used!

Evidence in favor of potential energy taking the form of mass, for the Electromagnetic Force, does exist. For some atomic nuclei, certain high-energy gamma rays can be absorbed (a purely Electromagnetic interaction). The nucleus that absorbs such a gamma ray becomes "meta-stable", and has acquired the potential to re-emit the gamma ray after some random amount of time. If the meta-stable nucleus is passed through a device known as a "mass spectrometer", it will be observed to have slightly more mass than a similar nucleus that has not absorbed a gamma ray. In fact, in accordance with $\mathbf{E} = \mathbf{mc}^2$, the amount of difference in mass between the two nuclei is equal to the mass-equivalent quantity of gamma-ray energy. Thus the meta-stable nucleus' potential energy, which *can* manifest as a gamma ray, exists as mass.

Fortunately, it is perfectly OK for us to go ahead and assume that, in the "system" of two tabletop magnets, a change in mass occurs whenever potential energy is exchanged for just-freed energy (or already free energy, if the exchange goes the other way). The quantity of change in mass in this system is so tiny as to be utterly ignore-able, and so results of ordinary calculations will be as identical as can be measured, when compared to the results of the distance-and-gradient assumption.

Getting back to the proton and electron, while we now can feel comfortable about claiming that the mass of this system changes when the particles combine to form a hydrogen atom, do we also really need to include the assumption of negative binding energy? It depends on the chosen reference frame!!! *Within* the atom, the answer is probably "yes", but from the perspective of a Distance Reference Frame, the answer is as likely to be "no" as it could be for describing a deuteron.

Here is where more detail is appropriate, than that presented for the deuteron situation, because Electromagnetism is a long-range force, while the Strong Nuclear Force is very short-range. If a proton and neutron are located too far apart, they mostly just ignore each other, while a proton and an electron will always interact, so:

i. Quantum Mechanics describes the interaction between electrically charged particles in terms of "the exchange of virtual photons". All charged particles constantly emit virtual photons in all directions; whenever such a photon is absorbed by another electrically charged particle, that particle is affected, somehow being "told" to be attracted or repelled. As you know, a proton and an electron always attract each other.

ii. The most interesting thing about any virtual photon is that *while* it exists, it is as perfectly real as any other photon. It contains real energy -- sure, it is *borrowed* real energy, courtesy of the Uncertainty Principle, but it is real energy all the same. And because its energy is borrowed, it only exists temporarily. The longer a virtual photon exists (equating with the farther it travels from its source-particle), the less energy it will have; just as Uncertainty allows its initial energy to appear from Nothing, so does it disappear back into Nothing, as time passes.

iii. Because they are real for as long as they exist, virtual particles are able to interact with and affect real particles. However, because their energy is borrowed, they are only allowed to interact in a subtle fashion; Nature never lets us *directly* detect virtual particles. (Detecting one means detecting its energy, which exists in violation of the Energy Conservation Law.) Most of the time, if ordinary particle A interacts with virtual particle B, then after the interaction, particle A's total energy must be unchanged. With just one exception, any such change would constitute a non-temporary violation of the Law of Conservation of Energy.

iv. That lone exception is associated with the conversion of potential energy into freed energy, because in this situation the total energy of a system remains Conserved.

v. Now imagine a virtual photon that a proton emits, and is absorbed by an electron. The electron acquires real kinetic energy, moving toward the proton. But remember, that gain in kinetic energy must be balanced by a loss of potential energy, which we already know takes the form of mass. Well, *since the proton emitted that virtual photon, it logically follows that the mass of the proton should be diminished by the amount of energy that the electron absorbed!*

vi. An altogether different area of Quantum Mechanics, "entanglement phenomena", offers support for the preceding. Two particles that interact can generally come away from the interaction with an overall value of (insert appropriate property here) that is known, but *how this total value is divided* between the two particles is unknown -- until either particle is measured. At that instant, no matter how far apart the two particles are located when the measurement is made, the measured particle acquires a specific property-value, and the other particle acquires the appropriate "entangled" property-value.

Back when this phenomenon was first predicted to be part of Quantum Mechanics, it was given the label of "spooky action at a distance" -- especially because it could violate the light-speed limit. Nevertheless, experimentation has shown that this is a Real Thing.

Convincing skeptics of one aspect of this phenomenon has always been difficult. "Why couldn't the specific values of the two particles have originated in their interaction? Then those values simply remain fixed thereafter, and if either is measured, of course the other will have an appropriate associated value -- it had that value all along."

Delicate experimentation has revealed two kinds of interaction, and they can be called "interactions we measure, and interactions we don't (or can't) measure". The description presented above as a query always applies to measurement-interactions; one particle leaving the scene of the interaction does indeed have a fixed property-value -- it brings us a piece of information -- and so of course other particle's value is known to us, too.

Entanglement interactions, however, never involve immediate measurement, and therefore the Uncertainty Principle guarantees that the particles involved will not have specific property values until one of them participates in a measurement-interaction. Physicists spent decades arguing about the preceding, and, bowing to the experimental evidence, have finally begun working with the idea that "spooky interactions" really occur.

Finally, the crux of this subdigression is this: Interactions involving virtual particles can *never* be of the measurement variety, and so it follows that they *can* be of the entanglement variety! Thus, if a proton emits a virtual photon that travels several light-years before being absorbed by an electron, we can indeed consider the possibility that the proton will instantly be reduced in mass by a tiny amount. (The amount is most extremely tiny because the virtual photon, while traversing light-years, had been ever-more-slowly returning fractions of its borrowed energy content back to Nothing for years. Meanwhile, ordinary real photons lose not one iota of energy, no matter how long they exist.)

vii. Naturally the next question to confront is, "A proton is constantly emitting virtual photons that are being absorbed, so why doesn't its mass entirely disappear almost immediately?" The answer, of course, is that the proton is simultaneously *absorbing* virtual photons emitted by *other* charged particles, and it all balances. About the only time a real change in mass should be expected is when a real change in the overall system occurs -- such as when an electron begins to move toward the proton, after absorbing a virtual photon: The electron acquired kinetic energy, so the proton lost mass (potential energy), and all is well with Energy Conservation.

viii. Meanwhile, the electron is in turn emitting virtual photons of its own, some of which get absorbed by the proton, causing it to move toward the electron. So the electron also loses some mass. Note, however, that in accordance with Special Relativity, as the two particles acquire kinetic energy, they also acquire relativistic mass! This tends to balance the potential-energy-as-mass which has been converted into the particles' motion.

ix. Now we have reached the place where Important Ratios once again enter the description. Because the proton initially has about 1836 times the mass of the electron, it accelerates rather more slowly than the electron. If we consider the acceleration of the electron and proton up to the point where they were about to form a hydrogen atom, then at that point it could be shown that the proton will have lost about 1836 times as much mass as the electron, in terms of conversion of potential energy into kinetic energy. (It won't have reacquired the same amount, in terms of relativistic mass, by absorbing virtual photons from the electron, but this nagging detail is about to become a moot point.)

x. As the hydrogen atom is formed, the kinetic energies of its constituent particles is converted into and emitted as real photons. At this point the potential energy, which had previously been converted into kinetic energy, escapes the system altogether. Finally we reach the goal, having started from using a Distant Reference Frame in the preceding descriptions: We can legitimately say that the hydrogen atom has less mass than the sum of a lone proton and electron, simply because those particles lose mass while forming the atom! And since they lose that mass in exact proportion, we are allowed to describe the atom from a local reference frame in terms of unchanged particle-masses and negative binding energy!

I submit, therefore, that regardless of how cumbersome it may be to work with a DRF, it certainly can yield consistent descriptions of events. Also, since the background concepts, which have to be applied to make it work, must be learned anyway, why *not* use a DRF once in a while?

5. As that digression ends, we can now think about the possibility that the preceding overall description for an Electromagnetic Force interaction will work in a similar manner for Strong Nuclear Force interactions, such as the formation of a deuteron from a proton and a neutron: If these particles approach closely enough, they begin to fall into each other's Strong Force "field gradient", exchanging virtual particles, losing potential-energy-as-mass, and acquiring kinetic energy. At the moment of deuteron formation, the kinetic energy is converted to gamma rays that escape the system, and the deuteron naturally ends up with less mass than the sum of the initial particle masses. Why not? (And to the extent that the Weak Nuclear Force exhibits repulsion or attraction like the others, the description may apply to it, too.)

Having finally returned to the subject of Gravitation, you should not be surprised if I start by saying that if we change the definition of "gravitational potential energy" from "height in a field gradient" to "mass", then the same overall description as just provided for the Electromagnetic and Strong Nuclear Forces can work for Gravitation, too. And as was previously mentioned with respect to two magnets on a tabletop, the amount of change in mass, for most Gravitational interactions, is so minute that it can be ignored. Thus as far as the average calculation is concerned, it remains perfectly OK to use Newton's method, imperfectly accurate though it might be, to compute magnitudes of potential and kinetic energy. The answers it provides will continue to be close enough to the truth, most of the time.

In the most extreme Gravitational situations, however, descriptions based on "potential energy is mass" will begin to differ from other descriptions. In one sense that is not good, because many of the existing descriptions are quite accurate -- so exactly what am I talking about, here?

1. One example concerns a neutron star. This extremely dense object can have an escape velocity of 60% of light-speed, so the terminal velocity of things falling onto it should be something like that, too.

2. Well, if a falling object acquires such a terminal velocity, and if Gravitational potential energy exists as mass, then a fair chunk of mass has to be converted, to become the kinetic energy of an object moving at 60% of light-speed. (But considering the sheer quantity of mass available in a neutron star, that is not a horrible problem!)

3. When the object impacts upon the surface of the neutron star, its kinetic energy will be transformed into heat, shock waves, all kinds of electromagnetic waves, and so on. The radiant energy escapes the system at once, but eventually all the other pieces of energy will gradually become radiant energy that also escapes the neutron star. (However, that process might take so long we have to recognize that *until* thermal motion converts and is radiated, that form of kinetic energy *is* part of the star's mass.)

4. The net effect is that, as things fall and pile up onto a neutron star, the rate at which the star's total mass increases will be different from a description based on the usual definition of Gravitational potential energy. Yet this is OK! --because we have no measurements supporting either description!

5. Both descriptions do have some things in common, such as the fact that energy radiates from a neutron star when something falls onto it. To the extent that we can measure events like that, neither description is different enough for us to decide which is right (they both describe the same quantity of released energy).

6. Possibly a pulsar is an appropriate thing to observe over the long term, to try to decide just how a neutron star's mass can grow with accumulation of infalling matter. If the infall is relatively constant, then the immediately-escaping radiation should gradually grow in frequency, as a consequence of increasing stellar mass, gravity field, and terminal velocity. So if Gravitational potential energy really does exist as mass, the rate of frequency-increase of the collision-radiation should be less than the rate described by assuming some other form for Gravitational potential energy.

Just pretend for a moment that there might be something to the overall idea that potential energy always takes the form of mass, regardless of the associated Natural Force. In the case of Gravitation, while we may match existing observations, and await observations for those cases where the alternate assumption leads to different results -- what other things might we gain from that pretense? How about matching those other aspects of General Relativity, which tell us that time goes slower and lengths get longer, deep inside a gravity well?

Knowing that the wave/particle duality (and an arbitrary single velocity) lets us associate reduced mass with lesser frequencies and longer wavelengths, and now assuming every particle that ever fell down a gravity well ended up with reduced mass at the bottom, we can indeed match QM with GR in that important area! We might even force ourselves to accept that assumption, due to the following argument:

1. G.R. is a well-verified theory; the longer lengths and the slower time associated with the depths of a gravity gradient are widely accepted by physicists.

2. Q.M. and the wave/particle duality are also well-verified; the association of momentum (and thus mass) with length and frequency is also widely accepted.

3. Therefore a mass' magnitude *must* change with its resting place (and implied constant velocity) in a gravity gradient, just as does its gravitational potential energy!

Looking back through this essay for loose ends, there seem to be two that require tying down:

1. A generic Distance Reference Frame was promoted as being useful when dealing with the Electromagnetic and Gravitational Forces, because such a frame would be located outside the infinite range of those phenomena. Hopefully, the extremely similar descriptions of how those Forces might work, as presented previously, from the viewpoint of the DRF, is something that a future T.O.E. will find to be a worthwhile part of the whole.

But one aspect of that idea remains to be stated: The Earthly laboratories of today's physicists are all located within several layers of gravity wells (Earth's, Sun's, Galaxy's, Local Group's, etc.), so, if the mass of anything is less within a gravity well than when located at the DRF, it means we don't actually know what the mass of anything really is! Sure, General Relativity lets us *assume* that masses observed here are the same in the DRF -- but we *don't* know how much "negative binding energy" represents the *actual* difference in measurements there, *relative* to our Earthly reference frame! And that lack of data, of course, will affect our ability to create an accurate T.O.E.

2. At one point it was mentioned that more needed to be described, about terminal velocities and black holes. Well, the original version of this essay presented a description of how an object's mass changed while falling in a gravitational field, based on the assumption that *it's own* mass converted from potential to kinetic energy. I need to formally retract that description. For two masses that begin to accelerate toward each other, and then collide (and converting/emitting their kinetic energies), that description failed to leave them with the same *ratio* of masses that they initially possessed. Thus it also failed to allow measurements of the masses, when they are at rest at different locations in their mutual field gradients (that is, in different reference frames), to yield equivalent results, as permitted by General Relativity.

By now, however, it should be clear that I am retaining the fundamental notion that gravitational potential energy should be accepted as taking the form of mass. It makes our descriptions of the Natural Forces more consistent -- a requirement stated at the start of this essay. Also, by incorporating details about the exchange of virtual gravitons, to allow each mass to become the source of kinetic energy for the *other* mass, then not only is the error concerning ratios fixed, but we advance the task of describing Gravitation in the same general terms of Quantum Mechanics as can be used for the other Natural Forces. This bodes well for a future Theory of Everything.