Discrepancies with the Recent Models of Nucleons

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Abstract

Recent theoretical calculations about the mass of the partons within protons have raised questions, specifically regarding what comprises the bulk of the mass of the nucleons. As a result of these recent theoretical calculations and the questions they precipitate, there are many new models of the nucleons that claim to have solved the question of the missing nucleon mass. This paper is an examination these recent nucleon models, exploring the accuracy of the science, the mathematics, and the concepts described therein.

1. Introduction

In 1964, the existence of quarks was proposed independently by Gell-Mann and Zweig [1, 2, 3, 4], changing the concept of the proton and neutron from homogeneously-charged particles to particles having electrical inhomogeneity. Since that time, much experimental evidence of quarks has confirmed their existence, mainly through the experimental evidence of deep inelastic scattering [5, 6, 7], a process used to probe protons and neutrons. Deep inelastic scattering provided the first convincing evidence of the reality of quarks. This is an extension of Rutherford scattering, but with higher energies and finer resolution to detect the inner components of the nuclei.

There are 6 different types of quarks, up, down, charm, strange, top, and bottom [8]. This is shown in Table 1.

Quark Flavor	charge	spin	Mass in MeV/c^2	Mass in kg	Measured or Theoretical Estimates of Mass
up	2/3 e	1/2	2.2	3.92211E-30	Theoretical Estimate
down	-1/3 e	1/2	4.7	8.37906E-30	Theoretical Estimate
charm	2/3 e	1/2	1,280.0	2.28196E-27	Theoretical Estimate
strange	-1/3 e	1/2	96.0	1.71147E-28	Theoretical Estimate
top	2/3 e	1/2	172,100.0	3.06816E-25	Measured
bottom	-1/3 e	1/2	4,180.0	7.45201E-27	Theoretical Estimate

Table 1. Quark characteristics, including the quark name, charge, spin, and mass, which is either theoretically estimated or measured.

Only two of these quarks are present in ordinary stable matter, the up and down quarks, and the remaining four quarks are short lived, with lifetimes much less than a second. These stable up and down quarks are the composite parts of stable matter, the proton and neutron. An up quark has a charge of 2/3 e and the down quark has a charge of -1/3 e, where e is an elementary charge of a proton.

Recent theoretical calculations of the mass of quarks imply that the mass of the quarks is much smaller than the mass of the nucleon [9]. These theoretical calculations posit that the mass of the quarks is only a small percentage of the mass of the nucleon, roughly 1 percent.

However, the mass of the up and down quarks cannot be measured directly. This inability to measure the quark mass directly is because quarks cannot be isolated from their nucleon, regardless of how much energy is used to try to unbind these quark from each other [10, 11, 12]. In various experiments, large amounts of externally-applied energy has been focused at protons, using particle accelerators and colliders in an attempt to break the bonds holding the quarks together. The goal of these experiments is to add external energy to the proton to separate the quarks, and thereby force the proton to break apart as a result of this added energy, in order to obtain an isolated quark as a result.

However, the external energy/mass, which must be added to a proton to break the chromodynamic bonds between the quarks, is larger than the energy/mass of the quarks. As a result, this added energy creates a quark/anti-quark pair, known as a pi-meson. Thus, the desired effect of the chromodynamic bonds being broken does not occur. Note, the mass of the pi-meson is 139.6 MeV/c^2 [13].

Although isolated quarks have not been detected experimentally to measure its actual mass, theoretical calculations have been made using chiral perturbation theory. These theoretical calculations are done by first experimentally measuring the mass of a pi-meson. Then by applying the theoretical predictions of the quantum chromodynamics chiral perturbation theory, a calculation can be done to determine the estimated mass of the quarks.

These calculations are extremely complicated, requiring the lattice quantum chromodynamics theory and contour improved perturbation theory to evaluate the ratio of two different types of quarks. In particular, using the theoretic assumptions of quantum chromodynamic chiral symmetry breaking, it is hypothesized that the mass of the up and down quarks are related to the square root of the mass of the pion [14, 15]. Using these assumptions, the ratio of the charmed quarks as compared to the strange quarks was first determined, and then this result was used to subsequently determine the ratio of the charmed quark to the up and down quarks. Comparing this value to the mass of the proton, which is 938.3 MeV/c^2, implies that the mass of the three quarks inside is roughly about 1% of the nucleon mass. The remaining 99% of the mass remains unexplained.

These numbers have sparked many new and recent theories regarding what makes up the missing 99% of the mass of the nucleons. Unfortunately, these new theories contain mistakes, errors, and unsubstantiated assumptions.

Here is an example, quoted directly, of the what these recent nucleon models are claiming [16].

> "In addition to mass that comes from quarks, another 32 percent comes from the energy of the quarks zipping around inside the proton, Liu and colleagues found. (That's because energy and mass are two sides of the same coin. Albert Einstein described that in his famous equation, $E=mc^2$. E is energy, m is mass and c is the speed of light.) Massless particles called gluons, which help hold quarks together, contribute another 36 percent of a proton's mass via their energy."

Here is another example, quoted directly [17]:

> "In quantum chromodynamics, the modern theory of the nuclear force, most of the mass of protons and neutrons is explained by special relativity. The mass of a proton is about 80–100 times greater than the sum of the rest masses of the quarks that make it up, while the gluons have zero rest mass. The extra energy of the quarks and gluons in a region within a proton, as compared to the rest energy of the quarks alone in the QCD vacuum, accounts for almost 99% of the mass."

Another example, quoted directly [18]:

> "Quantum chromodynamic binding energy (QCD binding energy), gluon binding energy or chromodynamic binding energy is the energy binding quarks together into hadrons. It is the energy of the field of the strong force, which is mediated by gluons. Motion-energy and interaction-energy contribute most of the hadron's mass.
>
> "Most of the mass of hadrons is actually QCD binding energy, through mass-energy equivalence. This phenomenon is related to chiral symmetry breaking. In the case of nucleons – protons and neutrons – QCD binding energy forms about 99% of the nucleon's mass. That is if assuming that the kinetic energy of the hadron's constituents, moving at near the speed of light, which contributes greatly to the hadron mass, is part of QCD binding energy."

And a final example, quoted directly [19]:

> "Protons are not made of quarks the way that a wall is made of bricks but rather like the way that a fire is made of flames. They are seething balls of spontaneously forming and annihilating quarks. (…)
>
> "The number of quarks plus the number of antiquarks depends on how closely you look. Just as a coastline seems to get longer as you zoom in (because the true coastline winds around every grain of sand on the beach), the number of quarks and antiquarks increases at finer scales."

Thus, depending on the model you look at, there are three concepts that make up the missing 99% of the proton mass:

1. The binding energy of the gluon particle field has a mass associated with it, due to the energy/mass equivalence.
2. The quark masses are inflated relativistically as they move at relativistic speeds inside the proton.
3. The additional of non-valance quarks.

These three concepts will be explored in Sections 2, 3, and 4 of this paper.

2. Binding Energy and Conservation of Energy

2.1. Overview of the Concept that Missing Mass Comes from Binding Energy

One of the biggest mistakes is a sign error made when accounting for binding energy, and in particular, this is a violation of conservation of energy.

This erroneous concept, that mass comes from binding energy, claims the binding energy holding the quarks together within the proton has mass. Furthermore, this erroneous concept claims that this mass of this binding energy contributes substantially to the proton's missing mass [20]. The models go into complex mathematical detail, performing lattice quantum chromodynamic calculations by using super computers, to determine the binding energy. However, the model fails to understand that binding mass must be subtracted from the mass of the component parts; it is not added to it. And herein lies the sign error.

This is a blatant violation of conservation of energy. This statement is not due to a naivete or incomprehension of the complexities of Quantum Chromodynamics. Rather, this statement is a fact of thermodynamics that the recent QCD models of the nucleon must, at some point, admit is correct. The rest of this section 2 will demonstrate this fact to be true.

2.2. Review of Correct Binding Energy Concepts

Before proceeding, a brief review of the actual correct binding energy concept is in order. Consider several isolated parts, not interacting with each other, and with no force or energy shared among them. These parts come together and form a bound object, an object that is made up of these component parts. These parts are now bonded together by some type of force, holding the component parts together in a stable bound object. This is represented in the Fig. 1.

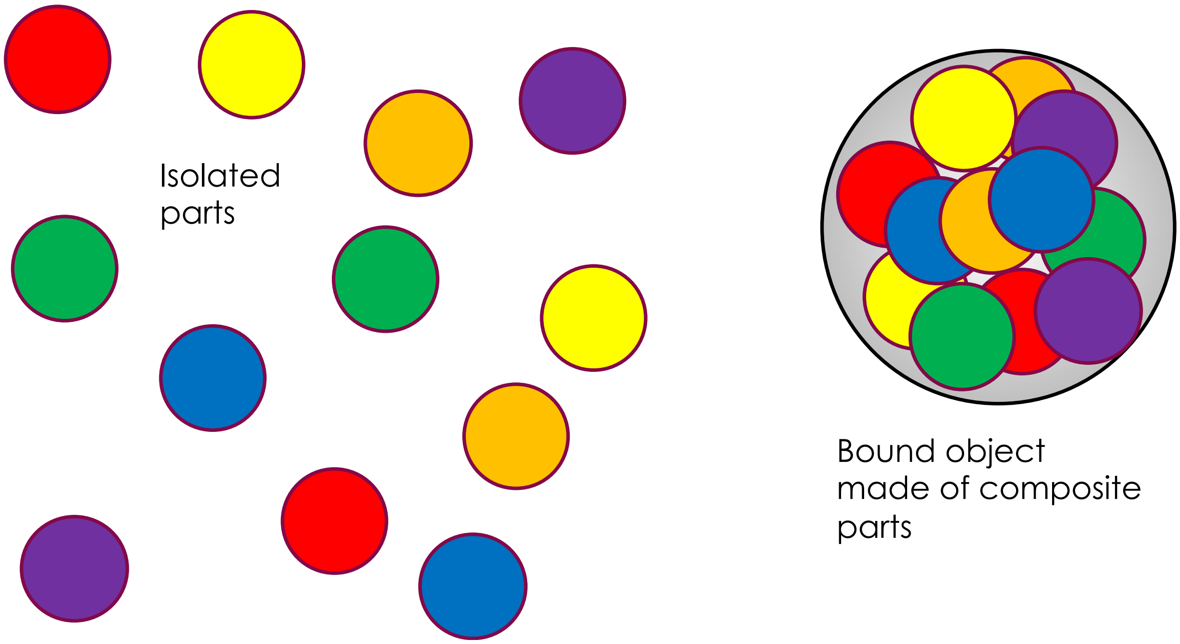

Fig 1. A bound object and its composite parts, before and after they are bound.

The total overall energy and mass of the bound object is less than the total overall energy and mass of the isolated component parts. The binding mass is defined as the difference between the mass of the bonded object and the mass of the isolated component parts. Similarly, the binding energy is defined as the difference between the energy of the bonded object and the energy of the isolated component parts. The binding mass and energy are related by $E=mc^2$, where c is the speed of light. By definition, that binding mass is positive, as is the binding energy. However, that binding mass is <u>subtracted</u> from the mass of the isolated component parts, in order to get the reduced and lower mass of the bonded object. Similarly, the binding energy is <u>subtracted</u> from the energy of the isolated component parts, in order to get the reduced and lower energy of the bonded object. This is shown in Eqs. 1a and 1b.

$$Mass_{bonded\ object} = Mass_{isolated\ component\ parts} - Mass_{binding} \qquad (1a)$$

$$Energy_{bonded\ object} = Energy_{isolated\ component\ parts} - Energy_{binding} \tag{1b}$$

From thermodynamics, it is known that all systems in nature have a tendency to seek their lowest energy state. If there exists an attractive force among a group of separate particles, then this manifests itself as a tendency of the particles to bond together into a lower energy object, an object that is also less massive. If allowed, a group of particles sharing an attractive force among them, will transform into a bound object, whose total mass is less than the mass of the isolated composite particles. The mass difference is determined by $E=mc^2$, where E is the energy difference between the system of isolated particles and the bound object.

Stated again for clarity, the mass of the bonded object is less than the sum of the masses of the isolated component parts. This is true for any stable bonded object, regardless of the type of force that holds the parts together. The bonded object is in a lower energy than the isolated parts. Explicitly, this is a known fact because energy was released into the external environment when the component parts bonded together. The energy that was released to the external environment lowers the overall energy of the system, and puts the bonded object into a lower energy than the isolated component parts. These same arguments apply similarly for the mass, because of the energy/mass equivalence.

2.3. Energy/Mass Equivalence

Energy and mass are equivalent, and can be regarded as simply different units of the same thing. They are related by the constant c^2. If the energy of the object goes up, the mass of the object goes up. If the energy goes down the mass goes down. They are not traded off like a teeter totter, wherein one goes up and the other one goes down. Rather they are simply different units of the same thing, a concept that is defined as the energy/mass equivalence.

If there is confusion about this concept, that mass and energy are <u>not</u> traded off for one another, then it must be remembered that the system of bound particles is <u>not</u> a closed system. Rather, when the binding occurs, energy is removed from the system and released to the external environment. Similarly, when the unbinding occurs, the addition of energy is required from the external environment.

2.4. Example of Nuclear Bonding Energy for Fusion

One example of binding energy is that of nucleons that fuse together to form a nucleus. Energy is released from the system into the environment when fusion occurs, thus the energy of the system is less. An external source of energy, such as the energy of a collider or particle accelerator, is required to break apart a nucleus.

Nuclear science readily confirms that binding energy lowers the mass and energy of a stable nuclide. An atom, made up of protons, electrons, and neutrons, is at a lower mass than its component parts. This is shown in Eq. 2, for the nuclear force [21].

$$Mass_{atom} = (Z \times Mass_{1_H}) + (N \times Mass_n) - (Mass_{binding}) \tag{2}$$

The subscript ^1H refers to the mass and energy of a hydrogen atom; this is used to properly and accurately include both the energy and mass of the electron as well as that of the proton. The Z is the number of proton and electrons, and N is the number of neutrons. $Mass_{1H}$ is the mass of the proton and electron, and N is the mass of the neutrons. The first two addends in this equation are the total masses of the isolated component parts. The subtrahend is the binding mass. Note that this binding mass, which is a positive number, is subtracted. It is not added. Thus, the mass of the bound nuclide is always lower than the masses of the isolated composite parts.

Similarly for binding energy, the energy of the bound nuclide is less than the energy of the isolated composite parts, by the amount of the binding energy. This is shown in Eq. 3.

$$Energy_{bound\ object} = c^2\left(Z \times Mass_{H1} + N \times Mass_n - Mass_{binding}\right) \tag{3}$$

Consider a proton and a neutron, isolated from each other, with no binding energy between them. If they get near enough to each other, they will bond via the nuclear force, to form ^2H. This nuclear force is *not* like the gravitational field, which gradually decreases to zero as the distance increases. Nor is the nuclear force like a stretchy spring, wherein the further the distance, the harder it pulls back. Rather the nuclear force can be compared to being more like a snap. If the nucleons touch each other, they snap together, forming a strong bond. And when the proton and neutron form this bond, energy is released into the environment in the form of gamma radiation. For a neutron and proton forming ^2H, this amount of released energy $E_{released} = 2.224$ MeV. The energy of the bound object (the ^2H) is less than the energy of the composite particles (the neutron and proton) by the amount of energy that was released into the environment. Furthermore, this amount of released energy is defined as the binding energy. The mass associated with this energy, the binding mass, is subtracted from the original masses of the neutron and proton. It would require 2.224 MeV or more of externally applied energy to pull the proton and neutron apart. This energy, supplied externally, is added back into the bonded object, in order to separate the two parts. Energy is always conserved throughout this process. Quantum physics, which is involved in this process, does not violate conservation of energy.

In nuclear physics, separation energies are the energies that must be added to the nuclide, by an external source of energy, in order to remove a nucleon. The separation energy for removing a neutron from a nuclide, S_n, is seen in Eq. 4. The final product of this neutron removal is the isotope with one less neutron. Energy must be added to the original nuclide from an external source, in order to remove a neutron.

$$S_n = [m({}^{A-1}_{Z}X) - m({}^{A}_{Z}X) + m_n]c^2 \tag{4}$$

where: X represents a generic nuclide.

Similarly for the separation energy of removing a proton, S_p, is the energy that must be added to the nuclide in order to remove a proton, as in Eq. 5.

$$S_p = [m({}^{A-1}_{Z-1}X) - m({}^{A}_{Z}X) + m_{H1}]c^2 \tag{5}$$

The mass of a stable bound object is always smaller than the mass of the isolated component parts. The difference is defined as the binding mass. That binding mass multiplied by c^2 is defined as the binding energy.

The laws of quantum physics obey the laws of conservation of energy; when nuclear fusion occurs energy is released. The bound system is at a lower energy and at a lower mass than the unbound system of parts.

2.5. Atomic Example of Binding Energy

Consider the binding energy of a chemical bond, formed by the interaction of electrons and atoms. For example, an external source of electric energy is required to separate water, a bound molecule, into the component atoms of oxygen and hydrogen. This external energy is absorbed by the system when the chemical bond is broken; therefore the energy of the system of unbound particles is more. Similarly, energy is released into the external environment when a bond is made. For example, when the gases of oxygen and hydrogen combine to form water, there is an release of light and heat into the external environment. Energy is lost from the system, therefore the energy of the system is less. The chemical bonds of electrons and atoms obey the laws of conservation of energy; when a chemical bond occurs, energy is released. The bound system is at a lower energy and at a lower mass than the unbound system of parts, by the amount of the binding energy/mass.

2.6. Electromagnetic Example of Binding Energy

Another example of binding energy is electromagnetic. Quantum physics says that the electromagnetic interaction is mediated by photons, much the way that the chromodynamic interaction is mediated by gluons. Consider the binding energy of two glass beads, one with a positive charge and one with a negative charge. If these beads are isolated from each other, there is no force or interaction between them. If they are brought closer together, there is an attractive force that will draw them even closer together; this is a force that is mediated by the photons going back and forth between these two charged glass beads. Assuming the beads are free to move, they will eventually contact each other, emitting energy in the form of a noise, a vibration, friction, and heat into the external environment. Although this may not be a lot of energy, it is nonetheless energy that is released by the system. The beads are bonded together by the electromagnetic force, and the by photons that mediate this force. Energy is lost from the system, and thus the two beads, in their bonded state, are at a lower energy. To pull the beads apart would require an external energy from an external source. This external added energy would bring their unbonded isolated state back up to where it was at the beginning.

The important thing to note about this particular example is that massless particles, the photons, are mediating the interaction. With regards to conservation of energy/mass, this mediation due to the massless photon particles is a process that conserves energy/mass.

2.7. Gravitational Example of Binding Energy

As another example, consider the force of gravity, a force that has both a field and binding energy. Consider several massive rocks that come together in outer space to form an asteroid. That asteroid has a gravitational field, and that gravitational field has energy. The gravitational field has binding energy, which has bound the rocks together to form the asteroid. When the rocks come together, they crash into each other and emit energy in the form of light and heat, into the external environment. (Any small debris that scattered away will eventually return, thus this is not the mass that is lost.) The released energy, which was released in the form of light and heat, is the energy that must be subtracted from the overall energy of the asteroid, as compared to its isolated composite parts. Thus, the overall energy/mass of the asteroid is slightly less than the sum of its isolated composite energy/masses. To unbind the asteroid back to the separate isolated rocks, a large external explosive energy would be needed to do so. This large explosive energy would provide the external energy to unbind the asteroid; however, that external energy source would have to be bigger than the gravitational binding energy of the asteroid in order to successfully dissociate it.

In this example, there is a force (gravity), and that force has a field (the gravitational field). That field has binding energy and binding mass. The overall energy/mass of the asteroid was reduced because a quantity of energy was lost into space when the asteroid was formed. Thus, the binding energy/mass is subtracted from the energy/mass of the composite parts. In order to return the asteroid to is composite isolated rocks, external energy must be added to it, to dissociate it.

The laws of gravity obey the laws of conservation of energy; when a gravitational bond occurs, energy is released. The bound system is at a lower energy and at a lower mass than the unbound system of parts.

2.8. Summary of Correct Binding Energy Concepts

Regardless of the force—electromagnetic, chromodynamic, nuclear, weak nuclear, gravity, or some new unusual force that has not yet been discovered—if two or more particles are bound together by a force, then the binding energy of that force is subtracted from the sum of the energies of the component particles. This subtraction of energy is due to the law of conservation of energy. This required subtraction of the binding energy is independent of the particular force involved. Table 2 [22] lists the three interactions of the microscopic world, i.e., of quantum physics, and all of the quantities that are conserved in certain interactions. It should be emphasized that no force is allowed to violate conservation of energy. All of these relations among conservation laws, invariance principles, and symmetries can be proved classically or quantum mechanically [23]. Stated specifically, the Strong Force of Quantum Chromodynamics does not violate conservation of energy.

Quantity Conserved	**Strong**	**Electromagnetic**	**Weak**
Energy	yes	yes	yes
Linear momentum	yes	yes	yes
Angular momentum	yes	yes	yes
Charge	yes	yes	yes
Electronic lepton number	yes	yes	yes
Muonic lepton number	yes	yes	yes
Tauonic lepton number	yes	yes	yes
Baryon number	yes	yes	yes
Isospin magnitude	yes	no	no
Isospin z component	yes	yes	no
Strangeness	yes	yes	no
Parity	yes	yes	no
Charge conjugation	yes	yes	no
Time reversal (or CP)	yes	yes	yes

Table 2. Applicability of the Conservation Laws to the observed interactions. “yes” means conserved, “no” means not conserved.

To summarize, particles held together by binding energy are in a lower energy and a lower mass than the isolated component particles. That is because, when a bond is formed, energy is released to the external environment. This energy is removed from the system of particles. The energy is less as a result of this released energy. Similarly, with mass. Conversely, to break a bond, an external energy must be added to the bound object to dissociate it. As a result, the isolated dissociated particles are in a higher energy state, due to the external energy that was added to the system. Thus, the bound particles in an object are at a lower energy state and a lower mass than the isolated component particles. The isolated component particles are at a higher energy state and a higher mass than the bound particles.

Using the complex quantum chromodynamic calculations, the recent models for nucleons have calculated the amount of the binding energy. However for proper conservation of energy, this binding energy must be subtracted from the rest mass of the isolated quarks, not added to it.

2.9. Gluons

The binding force holding the quarks together is postulated to be mediated by a massless particle called a gluon. These models do not claim that the massless gluons contribute to the mass of the proton. The models do claim, however, that the gluons have a "gluon particle field", and that the particle field has energy. This gluon particle field acts similar to the force of a stretchy spring--the further it is stretched, the harder and stronger it pulls back. However, it does not matter that the chromodynamic force is caused by massless gluons inside the proton. The electromagnetic force is thought to be caused by massless photons, and we know that the electromagnetic force abides by conservation of energy. The nuclear force is thought to be mediated by pions, and we know that the nuclear force abides by conservation of energy. Similarly, gravity is thought to be caused by massless gravitons, and we know that gravity still abides by the laws of conservation of energy. It is also known that the gravitational field has energy associated with it. However the energy of that gravitational field does not add to the mass of a bound object, as we saw in our examples. Similarly, the gluon particle field has energy associated with it, and, similarly, the energy of that gluon field does not add to the mass of the bound object.

If the proton is stable, the quantum chromodynamic binding energy is subtracted from the mass of the three component quarks, and overall net mass is less than the rest mass of the three isolated quarks.

2.10. Heisenberg Uncertainty Principle

The Heisenberg Uncertainty Principle is shown in Eq. 6.

$$\Delta E \Delta t > \frac{\hbar}{2} \qquad Eq. 6$$

This uncertainty principle states that the uncertainty in the energy, ΔE, of a particle times the uncertainty in the lifetime, Δt, of the particle can only be measured and discernible when that product is greater than Planck's reduced constant divided by two. Thus, this uncertainly principle allows for extremely small variations in energy that may violate conservation of energy for extremely short durations of time. These violations must be so small and so short in their duration, that they are indiscernible and unmeasurable. Specifically, according to the Heisenberg Uncertainty Principle, energy conservation may be violated as long as the product of the energy of the violation multiplied by the time duration of the violation is *less than* the reduced Plank's reduced constant divided by two, which is an extremely small value, 5.237×10^{-35} in MKS units. In other words, violations of energy are allowed only if the violation is so small that it is not detectable and not measurable. For this situation, the inequality sign usually associated with the Heisenberg Uncertainty Principle, is reversed to show the condition of this energy abnormality being undetectable and indiscernible. This is shown in Eq. 7, with the inequality sign properly and correctly reversed to demonstrate this condition of indiscernibility.

$$\Delta E \Delta t < \frac{\hbar}{2} \qquad Eq. 7$$

It should be noted that this uncertainty principle, depicted in Eqs. 6 and 7, is valid only for uncorrelated states of the considered particle. In particular, if either or both of the conditions exist:

- "phase memory"
- cross-correlation for different states of the same particle

then, for a given quantum system, the states are considered to be correlated. When such a correlation exists, the Heisenberg uncertainty relation of Eq. 6, is replaced by the Robertson-Schrödinger uncertainty relation, shown in Eq. 8.

$$\Delta E \Delta t > \frac{\hbar}{2}\frac{1}{\sqrt{1-r^2}} \qquad Eq. 8$$

where: r is the correlation coefficient, and $|r|<1$.

As seen in Eq. 8, the Robertson-Schrödinger uncertainty relation [24, 25] allows for an uncertainty that is different from that of Eq. 6, specifically that the product of the uncertainties may be larger that that allowed by Heisenberg.

The inequality sign is reversed for the condition of indiscernibility, as shown in Eq. 9.

$$\Delta E \Delta t < \frac{\hbar}{2}\frac{1}{\sqrt{1-r^2}} \qquad Eq. 9$$

In such cases, it is shown in [26, 27] that the existence of larger energy fluctuations over longer time intervals is possible.

However, even with this advanced understanding of the distinctions of the various Uncertainty Principles, this uncertainty allows for only a very small violation of energy to exist for only a very short duration of time. When the effects become macroscopic in size and time, quantum physics theories, including the uncertainty principles, adhere to the laws of conservation of energy. Uncertainty principles cannot violate conservation of energy for 99% of the visible matter in the universe, for billions of years.

As we have seen, electrons around an atom and molecule, such as water, are within the quantum realm of physics, and their binding energy obeys energy conservation laws. Similarly, nucleons in a nucleus are within the quantum realm of physics, and the binding energy of a nucleus obeys energy conservation laws. Consequently, a valid model of the partons inside a nucleon cannot naively claim that violations of the laws of conservation of energy are allowed to occur simply because the theory is quantum.

2.11. Mass Creation and Chiral Symmetry Breaking

The second rationale sometimes used as to why energy/mass conservation can be violated is due to the QCD chiral symmetry breaking. Below is a quote making this claim [28].

> "Chiral symmetry breaking is most apparent in the mass generation of nucleons from more elementary light quarks, accounting for approximately 99% of their combined mass as a baryon. It thus accounts for most of the mass of all visible matter."

This quote claims that the quantum chromodynamic chiral symmetry breaking is responsible for the generation of 99% of the energy/mass of the visible universe. However, this is an erroneous claim and a misinterpretation of QCD chiral symmetry breaking.

2.12. A Brief Description of Chiral Symmetry Breaking Theory

Experimentally, it is observed that the masses of the pseudo-scalar mesons, such as the pi-meson, are less massive than the masses of the vector mesons, such as the rho-meson. This mass difference between these two types of mesons, according to the theory, is due to spontaneous symmetry breaking of chiral symmetry within the fermion sector of QCD, specifically the broken chiral symmetry of the up, down, and strange flavors of quarks.

Here is an explanation, from a science textbook, of chiral symmetry breaking [29]. In this description, the chiral symmetry breaking is compared to an analogy of a large magnet, inside of which the numerous smaller atomic magnets are aligned. The term symmetry means "sameness", and in this particular ferromagnetic analogy, it refers to the "sameness" of the rotational direction of the atomic magnets.

> "This is an example of what physicists term spontaneous symmetry breaking: the symmetry of the lowest energy state is less than that of the interaction in question. Some people say that the expression 'spontaneous symmetry breaking' is a little misleading. The lowest energy state, or ground state, of the magnet, that in which all atomic magnets are aligned, does not share the rotational symmetry of the basic interaction between those atomic magnets. So the symmetry of the interaction is just hidden, but hasn't gone away. Hidden symmetry, they argue, is maybe a better expression than spontaneous broken symmetry. But it's the latter that has taken hold."

In this ferromagnetic example, the term "spontaneous symmetry breaking" means that although the atomic magnets are aligned, the large magnet can rotate in all directions. As a result, the large magnet is less "symmetrical" than the atomic magnets. However, even though the alignment of these atomic magnets is hidden, that alignment is still there. The term, “spontaneous broken symmetry” is really a misnomer, the symmetry is not broken; it is hidden. In this ferromagnetic example, the alignment and the symmetry of the atomic magnetics are hidden within the large magnet.

The book goes on to describe chiral symmetry breaking for QCD [30].

> “The source of that symmetry breaking is the vacuum. The vacuum fails to respect the chiral symmetry of the theory, and thus the vacuum’s symmetry is less. In the ferromagnetism example above, the aligned multitudinous atomic magnets gave a lowest energy configuration having a reduced symmetry relative to the interaction between those magnets, yielding Goldstone bosons. The chiral QCD case runs exactly parallel, the vacuum provides the analog of the lowest energy state, and its disregard for chiral symmetry mimicking the aligned atomic magnets’ disdain for the rotation-independence of the interaction.
>
> “In the ferromagnetic case, symmetry breaking results in magnons. In QCD, the result of breaking symmetry results is a fistful of mesons: three pions, π^0, π^+, π^- , four Kaons, K^0, anti-particle K^0, K^+, and K^- , and last but not least η. When the symmetry that is broken is exact, then the Goldstone bosons are massless. If the symmetry is not exact, but only approximate, then the result is, instead, low-mass spinless particles called pseudo-Goldstone bosons, instead of massless Goldstone bosons. Real up, down, and strange quark masses, though small on the energy scale of strong interactions, are not exactly zero, so real QCD does not have an *exact* chiral symmetry only an *approximate* chiral symmetry. So chiral symmetry breaking in QCD gives particles having a small mass, the eight mesons listed above. Through this mechanism, meson masses are linked to the (current) quark masses.
>
> “Indeed, chiral symmetry breaking is the route to estimating the up quark mass as 4 MeV and the down quark mass of 7 MeV. The effective masses of quarks bound into observable particles such as pions, protons, and neutrons, in other words the constituent masses of around 300 MeV, are due to the interaction of quarks with the surrounding chiral-symmetry-breaking vacuum. In this way, spontaneous symmetry breaking is responsible for effective quark masses. The chiral symmetry aspects of QCD are also the launch pad for another calculational tool that works over longer distance scales where conventional QCD perturbation theory breaks down. This chiral perturbation theory, which takes as its starting point the perfect chiral symmetry of a hypothetical QCD with massless quarks, then allows actual real masses to enter as perturbations.”

In other words, the theory of spontaneous chiral symmetry breaking, along with QCD chiral perturbation theory, can calculate the masses of the up and down quarks, as perturbations around an ideal situation of zero-mass quarks.

Here is another quote from a scientific peer-reviewed journal, showing the mathematical relationship of chiral symmetry breaking and the mass of the pions [31]:

> “In the standard understanding of the strong force interaction as defined by quantum chromodynamics, pions are loosely portrayed as Goldstone bosons of spontaneously broken chiral symmetry. That explains why the masses of the three kinds of pions are considerably less than that of the other mesons, such as the scalar or vector mesons. If their current quarks were massless particles, it could make the chiral symmetry exact and thus the Goldstone theorem would dictate that all pions have a zero mass.
>
> “In fact, it was shown by Gell-Mass, Oakes and Renner (GMOR) that the square of the pion mass is proportional the quarks condensate $M_\pi^2 = (m_u + m_d)B + \vartheta(m^2)$, with $B = |\langle 0|\bar{u}u|0\rangle / f_\pi^2|_{m_q \to 0}$ the quark condensate. This is often known as the GMOR relation and it explicitly shows that M_π=0 in the massless quark limit.”

As is noted in the quote above, the theory of chiral symmetry is idealized for massless quarks; if these quarks were massless, then this chiral symmetry breaking would not occur. However, since the quarks are not idealized massless quarks, they break this symmetry.

The masses of the pseudo-scalar mesons are specified by the of chiral perturbation theory. This chiral perturbation theory provides an internally-consistent argument, in which the pseudo-scalar meson masses are related to the square-root of the quark masses, but for only the smallest three quarks, the up, down, and strange. For the charm, bottom, and top quarks, their masses are much larger than the scale for the QCD spontaneous chiral symmetry breaking. Hence, the three larger quarks cannot be treated as small perturbations around the explicit symmetry limit of zero, and the chiral perturbation theory cannot be applied to these larger quarks.

What is important to highlight is that the theories of QCD chiral symmetry breaking do not claim that chiral symmetry breaking is able to generate energy/matter out of nothing. Rather, the models simply claim that chiral symmetry breaking is the basis for the predictions of the small masses of the up and down quarks. The misconstrued claim that chiral symmetry breaking is responsible for the creation of 99% of all visible energy/mass in the universe is a erroneous concept. It is a concept not made by the peer-reviewed scientific journals, but rather by a naïve misinterpretation of the model.

In conclusion, the creation of energy/mass due to chiral symmetry breaking should not be considered as more valid or more credible than the laws of thermodynamics, such as conservation of energy.

2.13. Experiments to Break Apart a Proton

The proponents of these recent nucleon models claim that QCD gluon binding energy creates a positive mass, thereby making the proton heavier. However, if these proponents actually did believe that the binding energy of the quarks somehow makes the proton heavier, then in the experiments attempting to separate the quarks would have to pull that binding energy out of the proton. However they do not do this in their experiments. Rather they add energy into the proton, energy from an external source, such as a particle acceleration or collider. They add this energy in an attempt to break the QCD bonds and dissociate the proton into its component parts. This is an extremely important statement and bears repeating.

Experiments attempt to separate the quarks by adding external energy into the proton. This is done in order to put the proton into an excited energy state, and to use that added external energy to break the chromodynamic bonds within the proton.

In other words, the particle physicists cannot deny that they do, indeed, acknowledge that the object of a bound proton is at a lower energy state than its composite parts. This is why they add external energy into the proton, to try to increase the energy of the proton, to break the chromodynamic bonds. If the particle physicists truly thought that the binding energy was some hypothetical thermodynamically-impossible "substance" that increased the mass of the proton, they would not try to break the chromodynamic bonds by putting energy into it.

The mathematics of this chromodynamic bond is very complicated and difficult to understand, requiring computers to calculate it. From this very complicated mathematics and computations, the models have derived a value for the binding energy of the chromodynamic force between the quarks. Those calculations, and that complexity behind them, is not being questioned here. The deserved respect of the particle physicists who have made these calculations is not being questioned here; they are highly respected people and they remain respected. The calculations of the absolute value of the binding energy are not being questioned here.

What is being questioned, and called out as incorrect, is that the binding energy is being erroneously added, rather than being properly subtracted.

2.14. Conclusions about Binding Energy

Since these quarks are bound together inside a nucleon, held together by the extremely strong binding energy of the chromodynamic force, the resulting collection of three quarks bound together in a nucleon is less massive than the mass of the three isolated quarks, as seen in Eq. 10.

$$Mass_{nucleon} < \sum_{i=1}^{3} Mass_{quark\_i} \tag{10}$$

Regardless of the force involved, regardless of quantum uncertainty, regardless of quantum chiral symmetry breaking--the QCD binding energy of the three quarks does not increase the mass of the nucleon. As mentioned previously, this statement is not due to a naivete or incomprehension of the complexities of Quantum Chromodynamics. Rather, this statement is a fact of thermodynamics that is incontrovertibly correct.

3. Relativistic Mass Inflation

3.1. Overview of Concept that Missing Mass is Due to Relativistic Mass Inflation

Another concept to make up the missing 99% mass is to make the three quarks move extremely fast, such that they inflate their mass relativistically and become much more massive, enough so to account for the 99% of the missing proton mass. This relativistic speed increases the mass of the quarks due the relativistic mass inflation from Einstein's special theory of relativity, as shown in Eq. 11.

$$Mass_{relativistic} = \frac{Mass_{rest}}{\sqrt{1-\left(\frac{v}{c}\right)^2}} \tag{11}$$

As can be ascertained from this equation, when the velocity v is close to the speed of light c, the denominator in this equation becomes less than 1, and the relativistic mass become larger than the rest mass, as a result. To increase the velocity of an object, external energy is added to the object, in the form of kinetic energy. This added energy thus increases the overall energy and mass of the object. Thus, Eq. 11 is simply another way of expressing the equation of $E=mc^2$. In this case, the energy added to the object is in the form of kinetic energy, enough to bring its velocity up to relativistic speeds. This process of increasing in the mass of an object, by adding kinetic energy to the object, is known as relativistic mass inflation.

3.2. Relativistic Mass Inflation Applied to Quarks in a Proton

If this relativistic mass inflation is to account for 99% of the mass of the proton, then the quarks need to go 0.9999349 times the speed of light, as shown in Calc. 1.

$$0.99 \times Mass_{proton} = \frac{(2.5+2.5+5.6)}{\sqrt{1-\left(\frac{0.9999349\ c}{c}\right)^2}}$$

$$0.99 \times 938.3\ \mathrm{MeV}/c^2 = \frac{(10.6)}{\sqrt{1-(0.9999349)^2}}$$

$$928.9\frac{\mathrm{MeV}}{c^2} = 928.9\ \frac{MeV}{c^2}\ \ check \tag{Calc. 1}$$

However, if the quarks are moving at 0.9999349 c, the quarks would instantly be hurled from the proton. This added kinetic energy, which is needed to inflate the relativistic mass of the quarks, would give the quarks so much momentum that they would instantly explode out of the proton.

That is, <u>unless the binding energy is stronger</u> than this relativistic kinetic energy.

In order to prevent the quarks from instantly exploding out of the proton, we need a binding energy that is stronger than the relativistic kinetic energy of the quarks, as shown in Eq. 12.

$$E_{binding} > E_{kinetic}\ where{:}\ E_{kinetic} = (m_{relativistic} - m_{rest})c^2 = (\Delta m)c^2 \tag{12}$$

To clarify, the binding mass must be greater than the relativistic mass increase of the quarks, if the proton is to be a stable particle. Thus the two energies, the binding energy and the relativistic kinetic energy, are in an energetic tug-of-war with each other.

As is evident in the quotes above for these new models, they are claiming that the kinetic energy <u>adds</u> to the binding energy. However, this concept is incorrect. Binding energy and kinetic energy oppose each other; they subtract from each other, they do not add to each other. In order for the proton to be stable, with super-speed relativistic quarks zooming around inside it, the binding energy of the chromodynamic force would have to be stronger than the kinetic energy of the relativistic mass inflation. Otherwise, the proton would explode from its own internal kinetic energy. Thus, if we use relativistic speeds to increase the mass of the quarks, the binding energy of the proton must reduce that mass by <u>more than</u> that amount. Herein lies another mistake, and another sign error, of these current nucleon models. Relativistic mass inflation cannot be used to account for the missing mass of the proton.

If the quarks are to be bound inside the proton, then the binding energy has to be more than their kinetic energy, in order to contain them inside the nucleon. If the proton is to be stable, then the relativistic mass increase of the quarks cannot be more than the mass decrease of the binding energy. In other words, when comparing the mass of the proton to the rest mass of the isolated quarks, there must be an overall net decrease in the mass--a decrease which is caused by the binding energy being greater than the kinetic energy. The net mass of the three quarks inside a stable proton cannot be increased by kinetic energy more than the mass of the proton is decreased by the binding energy.

3.3. Example of Binding Energy vs. Kinetic Energy

For example, imagine several glass beads sitting on a flat smooth turntable, connected together by the thin threads of a spider web. The threads of the web are the binding force holding the beads together. If that turntable starts to spin and gives the beads some kinetic energy, then the beads will fly off the turntable, because the thin spider webs are too weak to hold the beads together against the centrifugal forces. However, if the spider webs were replaced by sturdier wires glued to the beads, then the beads would not be able to fly off the turntable. This simple analogy is the similar to for the kinetic energy and binding energy of the quarks inside a proton. The binding energy must be stronger than the internal kinetic energy for a stable object.

3.4. Summary of Mass Inflation Concept

The proton is stable only if the binding energy of the chromodynamic force is stronger than the internal kinetic energy of the component parts; otherwise, the proton would explode due the internal kinetic energy of its own quarks. The binding energy of the composite particles is in direct conflict with their kinetic energy. The binding energy of the object reduces the mass of the object. Conversely, the kinetic energy of its internal particles increases its energy. In order for the object to be stable and not explode, the binding energy of an object must be greater than its internal kinetic energy. Thus, the decrease in mass due to binding energy must be more than the increase in mass due to it internal kinetic energy.

To summarize, within a stable bound object, the two energies--the kinetic energy of the composite particles and binding energy holding them together--oppose each other and are in direct conflict with each other. These two energies, the internal kinetic energy and the binding energy, are not added together, rather they are in conflict with each other. In order for an object to be stable, the binding energy must be more than the kinetic energy. This means that the overall mass of a stable bound object is less than the rest mass of its composite particles, regardless of the relativistic velocity of the composite particles.

Hence the idea that increasing the mass of the quarks by using relativistic mass inflation is not a valid concept for a stable nucleon. If the quarks are to be bound together inside a stable nucleon, the overall mass of the bound object must be at a lower mass than the rest mass of the original isolated composite parts.

4. The Addition of More Non-Valance Quarks

4.1. Overview of Concept that Missing Mass Comes Additional Quarks

Another concept for adding mass to the proton is to add more non-valance quarks into the proton, hundreds of them, to make up for the missing 99% of the mass. The idea behind this concept is simply to add more quarks, called non-valence quarks or "sea" quarks, into the nucleons, to give the nucleons more mass. The quarks must be added in groups of six to keep the colors, spins, and electric charges neutral. At the very least, this gives nine quarks inside a nucleon: three valance quarks and six non-valence quarks.

4.2. Additional Non-Valance Quarks and the Pauli Exclusion Principle.

According to the Pauli Exclusion Principle, there cannot be particles in a quantum object with the same set of quantum numbers. Quarks are quantum objects. Historically, this is why colors were assigned to the quarks, in order to distinguish the three quarks from one another. Hence the quarks were assigned colors--red, green and blue--to distinguish their properties and provide them with different quantum states. With regards to color, there cannot be two red quarks or two green quarks or two blue quarks inside the same nucleon, otherwise they would conflict with the Pauli Exclusion Principle [32]. All of these additional non-valance quarks would violate the Pauli Exclusion Principle.

4.3. Additional Non-Valance Quarks and the Heisenberg Uncertainty Principle.

All of these additional non-valance quarks would also violate the Copenhagen Interpretation of the Heisenberg Uncertainty Principle. The Heisenberg Uncertainty Principle claims that the uncertainty in the momentum of an object times the uncertainty of its position cannot be smaller than Plank's reduced constant, divided by 2. This is similar to the equation as discussed in section 2, but with the two conjugate-pair uncertainties converted to momentum and position. This is shown in Eq. 13.

$$\Delta p \Delta x \geq \frac{\hbar}{2} = 5.237 \times 10^{-35}\ m^2 kg/s \tag{13}$$

This uncertainty relationship for quarks is now examined, by first using a non-relativistic calculation. The uncertainty in the position of the quarks is the diameter of the proton, D_{proton}=1.682x10^{-15}. The mass of the up quark as 3.922 x10^{-30} kg. For non-relativistic non-inflated mass, the largest number we can reasonably use for the uncertainty in the velocity of the quarks is about one tenth the speed of light, or 2.99 x 10^{7} m/sec. This gives us a small enough mass inflation that we can reasonably consider it to be non-relativistic. Using no mass inflation and 0.1c as the uncertainty in the velocity, and putting these numbers in Eq. 9 in MKS units, we get Calc. 2:

$$\Delta p \Delta x = (3.922 \times 10^{-30})(2.99 \times 10^{7})(1.682 \times 10^{-15}) = 1.97 \times 10^{-37}\ m^2 kg/s \qquad (Calc.2)$$

The Heisenberg Uncertainty Principle insists that this product of uncertainties must be bigger than 5.237x10^{-35} $m^2 kg/s$; clearly it is not. Thus, the addition of hundreds of non-valence quarks into the proton now violates not just one, but two, of the foundational pillars of quantum physics.

Without mass inflation, the mere existence of a 2.6 MeV/c^2 quark confined inside the proton violates the Heisenberg Uncertainty Principle. Relativistic mass inflation must be used to increase the mass of the quarks, such that they do not violate the Heisenberg Uncertainty Principle. Indeed, this relativistic mass inflation is how the theoretical models attempt to prevent this violation [33]. This possibility is explored below.

4.4. Relativistic Mass Inflation to Avoid Violating Uncertainty Principles

Again, it is assumed that the uncertainty in the quark position is the diameter of the proton, D_{proton}. The mass of the quark is now the relativistically inflated mass. Combining Eqs. 8 and 9, results in Eq. 14.

$$\left(\frac{m_{quark\_rest}}{\sqrt{1-\left(\frac{v_{quark}}{c}\right)^2}}\right)(v_{quark})(D_{proton}) \geq \frac{\hbar}{2} \qquad (14)$$

Since this is a transcendental equation for the quark velocity v_{quark}, this is solved by iteration. Using the values of D_{proton}=1.682x10^{-15} meters, m_{quark_rest}=3.922x10^{-30} kg, and h/4π=5.275x10^{-35} m^2kg/s, and c=2.9979 x 10^{8} m/s, we get the required mass of the quark as 1.04689x10^{-28} kg, and the uncertainty in the velocity is 0.999298 c. This is checked below, in Calc. 3.

$$\left(\frac{3.922 \times 10^{-30}}{\sqrt{1-\left(\frac{0.999298\,c}{c}\right)^2}}\right)(0.999298)(2.9979 \times 10^{8})(1.682 \times 10^{-15}) \geq 5.275 \times 10^{-35}$$

$$(1.04689 \times 10^{-28})(0.999298)(2.9979 \times 10^{8})(1.682 \times 10^{-15}) \geq 5.275 \times 10^{-35}$$

$$5.275 \times 10^{-35}\frac{m^2 kg}{s} \geq 5.275 \times 10^{-35}\frac{m^2 kg}{s}\ \ check \qquad (Calc.3)$$

These values narrowly allow the up quark to fit within the confines of the Heisenberg Uncertainty Principle. This required minimum mass is 1.04689x10^{-28} kg = 58.72 MeV/c^2. This is 26.7 times the original rest mass of the quark, and for the one quark, it is 6.258% of the mass of a proton.

If the quarks are in correlated states inside the proton, the Robertson-Schrodinger uncertainty principle of equation 8 would apply. Similar modified uncertainty relations take place for the uncertainty in spatial coordinates and momentum for particles in a coherent correlated state, shown in Eq. 15.

$$\Delta p \Delta q \geq \frac{\hbar}{2}\frac{1}{\sqrt{1-r^2}} \qquad Eq.15$$

This would give a different value for the required inflated mass needed to satisfy the uncertainty principle, depending on the correlation coefficient. Regardless, these quarks would instantly explode from the proton, unless the binding mass is more than the relativistic mass inflation, as was discussed in Section 3. Even if hundreds of quarks are added, and their mass is inflated with relativistic speeds, they must be held together by a binding energy that is stronger than their kinetic energy. And recall from section 2, that binding energy is subtracted, not added, and as a result, all of that inflated mass is negated by the binding. What remains is a proton that is less massive than the sum of the rest masses of the quarks inside it.

4.5. Possible Ways to Revise These Recent Nucleon Models with Hundreds of Quarks.

One possible way to revise these models, to remove this violation of the Pauli Exclusion Principle could be done conceptually by adding more colors, in groups of six, to the theory of chromodynamics. However, we need hundreds of colors as determined in Section 4.4. This would require that quantum chromodynamics be rewritten to accommodate hundreds of colors. Not only is this option theoretically unattractive, another issue is that the experimental data strongly implies that there are only three colors [34].

In order to fit within the confines of the Copenhagen Interpretation of the Heisenberg Uncertainty Principle, the new models of the nucleons would also have be revised. One possible way to revise the models in order to remove this violation of the Uncertainty Principle, conceptually, would be to claim that the Copenhagen Interpretation of the Heisenberg Uncertainty Principle does not apply to quarks since quarks are not isolated particles. Or perhaps it could be claimed that Einstein was right all along about the Copenhagen Interpretation of the Heisenberg Uncertainty Principle. Again, these options are unattractive to most physicists.

4.6. Fractals, Antimatter, and the Residual Quantum Chromodynamic Model

The nuclear force is the force which holds the nucleons together in a nuclide. The most widely accepted model of the nuclear force is the Residual Quantum Chromodynamic model. This Residual Quantum Chromodynamic Model would have serious difficulty reconciling itself with these recent nuclide models and the “seething balls of spontaneously forming and annihilating quarks” purported to exist inside each nucleon. Specifically, the residual quantum chromodynamic bond that exists between the inter-nucleon quarks would have extreme difficulty surviving the continuous creation and annihilation of its quarks. The fractal concept would add another absurdly complicated dimension into these already complex models. Any reconciliation between these recent models of the nucleon and the Residual Quantum Chromodynamic Model would be extremely difficult.

4.7. Conclusion about Adding More Quarks

Thus, adding more quarks does not work well as a concept--requiring revisions not only of the recent nucleon models, but also of Quantum Chromodynamics and the Heisenberg Uncertainty Principle. However, such revisions are not necessary if the binding energy and kinetic energy are simply accounted for correctly, without sign errors. The addition of more non-valance quarks is an unattractive and troublesome idea for numerous reasons. It seems to be a better idea to maintain the concept of three quarks and to simply use proper accounting for the kinetic and binding energies.

Thus, we are back to the conundrum of having 99% of the mass of the proton unexplained. However, recall that this 99% missing mass is based on the theoretical calculations. It is not based on actual experimental measurements of the quark mass.

5. Theory versus Experiment

5.1. The Standard Model

The complex calculations of the Standard Model have theoretically predicted that quarks have an unexpectedly small mass. As detailed in the 2005 article “Beyond the Standard Model” [35, 36], it is stated that the Standard Model is inherently an incomplete theory, with revisions and changes being applies as needed. The Standard Model should not be considered, at this point in the progress of physics, as the absolute truth. For example, it does not explain gravity, dark matter, dark energy, neutrino mass, or the anti-matter/matter asymmetry of the universe. Thus, a revision of one small part of it, specifically the chiral symmetry breaking, might be appropriate to adjust for the masses of the quarks.

Lower Limit of Quark Mass

Although it is not the main focus of this paper, an interesting result becomes obvious, and should be mentioned. With the understanding that binding energy is subtracted from the mass of the isolated component particles, this information readily gives us a lower limit to the mass of the up and down quarks. If the quarks inside a proton cannot be unbound by the addition of 139.6 MeV/c2 of energy, then we know the binding energy is at least this much. And, this same binding energy has decreased the mass of the three isolated quarks by at least that amount. Therefore, the rest mass of the partons is at least the mass of the proton plus the amount of 139.6 MeV/c^2. This can be determined by rearranging Eq. 1. Including the inequality, this is shown in Eq. 16. The calculation is shown in Calc. 4.

$$Mass_{component\ parts} \geq Mass_{bonded\ object} + Mass_{binding} \tag{16}$$

$$Mass_{component\ parts} \geq 938.3\frac{MeV}{c^2} + 139.6\frac{MeV}{c^2} \geq 1077.9\ \frac{MeV}{c^2} \qquad (Calc. 4)$$

Assuming there are no other massive particles, as yet undiscovered, inside the proton, this gives the sum of the masses of the three quarks to be at least 1077.9 MeV/c^2. Thus, each of the masses of the quarks are at least 350 MeV/c^2 = 6.4 x 10^{-28} kg. However, because of the sign error made in accounting for the energies, this simple determination of the lower limit for the mass of the quarks has not previously been recognized.

Since the up and down quarks have a much larger mass than was previously thought, and their masses are too large for perturbation theory to effectively be applied to them. This means that the up and down quarks should not be treated as small perturbations around the explicit symmetry limit of zero mass, and the chiral perturbation theory should not be applied to them.

Also, the experimental attempts to dissociate the proton are done by adding energy/mass into the proton. There are no experimental attempts to pull energy out of the proton in order to dissociate it. Because of these experiments, scientists already know that the quarks confined inside the proton are in the lowest energy state, specifically the proton is in a state of lower energy than the dissociated quarks would be. As is demonstrated by the experiments that attempt to separate the quarks by adding external energy into the proton—it is known that the binding energy/mass of the bound system of a proton is at a lower energy/mass than the isolated quark components.

By correctly accounting for the additional energy needed to dissociate a proton, the experimental data directly contradicts the theoretical estimates of the chiral perturbation theory of small quark masses for the up and down quarks.

5.2. Conclusions about Theory vs. Experiment

"It doesn't matter how beautiful your theory is, it doesn't matter how smart you are. If it doesn't agree with experiment, it's wrong ..." –Richard Feynman.

6. Overall Conclusions

There are sign errors in the new models of the proton, errors that are made when trying to account for the various energies and masses. Also there are violations of Thermodynamics, Energy Conservation, Pauli Exclusion Principle, and the Heisenberg Uncertainty Principle. Furthermore, these new nucleon models cannot be easily reconciled with the currently-accepted models of the nuclear force, such as the Residual Chromodynamic model of the Standard Model.

By applying proper accounting of the energy/mass within the nucleon, the following conclusions can be made. There are only three quarks inside each nucleon. Assuming there are no other as-yet-undiscovered massive particles inside the proton, then each of these three quarks inside a nucleon has a mass of at least 350 MeV/c^2. None of the quarks violate the Pauli Exclusion Principle. None of the quarks violate the Heisenberg Uncertainty Principle. There is no violation of Thermodynamics. There is no violation the Conservation of Energy. And most importantly, there are no sign errors.

Nucleon models are the building blocks for Nuclear Force models. Similarly, the nucleon models are used in Cosmology for a better understanding of the beginnings of the universe. For a better understanding of nuclear physics and cosmology, nucleon models must be free of blatant violations of sign errors, violations of thermodynamics, violations of conservation of energy, and violations of the foundational pillars of modern physics. When trying to account for the nucleon masses, the recent models of the nucleons are severely flawed. These recent models of nucleons should not be endorsed by the scientific community as correct.

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