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E-Book

The Short-Range or "Particle" Forces: Part I

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Abstract

The strong force (in two expressions) is responsible for the binding of compound atomic nuclei and the binding of quarks in the class of heavy composite particles, the hadrons. Hadrons consist of baryons (containing 3 quarks) and mesons (containing quark-antiquark pairs).

Another short-range force, the weak force, is responsible for the creation, destruction, and transformation of *single,* unpaired elementary particles (quarks and leptons). Both forces are to be understood in terms of energy, charge, and especially symmetry conservation. The strong force conserves whole quantum units of charge (in baryons and mesons), and achieves "least bound energy" nuclear configurations (in compound atomic nuclei); the weak force ensures the invariance of all conserved parameters in elementary particles during the creation, destruction, or transformation of *single,* unpaired particles - irrespective of time or place. (See: "The Higgs Boson and the Weak Force IVBs".)

Introduction: The Particle Spectrum

The energy forms of our Universe are generally divided into two types (always a dichotomy!), the bosons and fermions (free and bound forms of electromagnetic energy - light and matter). These are distinguished on quantum mechanical grounds, bosons having integer spins (0,1,2) and fermions having half-integer spins (1/2, 3/2) - in units involving Planck's energy constant (h/2pi). Bosons can superimpose their energy upon one another, fermions cannot, obeying Pauli's "Exclusion Principle" (photons can pile up to any energy, electrons remain individually distinct). The field vectors of the forces are bosons - photons, gravitons, gluons, IVBs (Intermediate Vector Bosons) - and are massless except for the IVBs. The particles which constitute atomic matter are fermions - leptons, quarks, neutrinos - and are massive (apparently neutrinos have a tiny mass). The field vectors of the weak force fall between these classes, as massive bosons or force carriers; for this reason they are given the awkward name of "Intermediate Vector Bosons" (IVBs) (see: "The Particle Table").

In the particle spectrum we will generally be discussing the fermion class of particles (the constituents of atomic matter), in addition to some short-range boson field vectors (mesons, gluons, and IVBs). Fermions themselves are subdivided into two sections, the leptons and hadrons. Hadrons include any particles containing quarks: of these there are only two kinds, the mesons, which contain quark-antiquark pairs, and the baryons, which contain three quarks, the latter familiar to us as protons and neutrons. Leptons do not contain quarks; they are truly point-like elementary particles, with no internal parts, including the electron and its neutrino, and two similar but heavier "family members", the muon and tau and their neutrinos; quarks also exist in 3 "families" of 6 related particles of various discrete and quantized masses ("up-down, charm-strange , top-bottom"). Leptons are the only truly elementary fermions; hadrons are not elementary, as they contain sub-units bearing fractional charges, the quarks. Our primary interest is the spectrum of elementary leptonic particles and its relationship to the quarks. (In more familiar terms, how are electrons and neutrinos related to protons, neutrons, and mesons?)

Leptons and Leptoquarks

The leptonic spectrum of elementary particles consists of only three known massive members, the electron, muon, and tau. These particles are identical except in terms of mass (and a conserved charge known as "number" or "identity"), the electron being the lightest, the tau the heaviest. Each is accompanied by its own neutrino, a (nearly) massless particle. There is, as always, a corresponding set of antiparticles and antineutrinos. The neutrino carries the "identity" charge of its massive leptonic partner. "Identity" charge, otherwise known as "number" charge, is a strictly conserved charge of elementary particles; its origin as a symmetry debt as well as the practical significance of the leptonic particle series as alternative charge carriers of electric and identity charge, is fully discussed in "Symmetry Principles of the Unified Field Theory". Neutrinos are the "bare" or explicit form of lepton number or identity charge, which is also carried in "hidden" or implicit form by all massive leptons (including the hypothetical leptoquark). (See: "The Weak Force Identity Charge".)

A fourth member of this leptonic spectrum is thought to exist, the hypothetical and very massive "leptoquark". This particle forms the bridge between the leptons and quarks. My personal view of this primordial particle is that it formed as a sort of "fractured" heavy lepton. One possible "rationale" for breaking an elementary particle into three parts (which became the quarks) is that a composite particle can absorb much more energy than an elementary one, as its internal parts can be squeezed together like a set of compressible springs (against the resistance of Pauli's Exclusion Principle). The increasing mass of the elementary leptonic spectrum is therefore explained on the pragmatic grounds of absorbing or "packaging" energy ever more efficiently in the early moments of the Big Bang, when the Universe contained very little space but a lot of energy. The leptoquark is the ultimate energy absorber, compactor, or energy "package".

Of course, almost any amount of energy can be stored in the momentum of a massive particle (via the relativistic mass increase due to Einstein's Special Relativity) - also a useful feature for preventing the gravitational collapse of the early Universe. However, an even more compelling reason to create a composite primordial particle is that such a particle can arrange its internal quark sub-units to produce an overall condition of electrical neutrality - like the neutron. Electrical neutrality is a necessary precondition for symmetry-breaking among particle-antiparticle pairs during the "Big Bang", otherwise matter-antimatter annihilations between electrically charged particles cannot be avoided. The primordial mass-carrying, symmetry-breaking particle must therefore be a composite, electrically neutral particle - an electrically neutral leptoquark or its analog. (Only such neutral particles can live long enough to undergo the necessary weak force asymmetric decay process.)

When the leptoquark is fully compressed by the external pressures of the Big Bang, it is in every respect a heavy lepton, the heaviest member of the leptonic particle spectrum. But when the pressure is relieved, its quarks spring apart from mutual repulsion, and the particle becomes a heavy baryon (hyperon). This is why the leptoquark is the bridge between the leptonic and quark series.

As a fractured elementary particle, the baryon must be held together by permanently confining internal forces, the strong force carried by "gluons", exchanged between the "color" charges of the quarks. For quantum mechanical and symmetry conservation reasons, the baryon cannot be allowed to fly apart; given the absence of antimatter there would be no way to cancel, neutralize, or annihilate the partial charges of its sub-elementary fragments. Permanent confinement to a "virtual" elementary charge state of whole quantum charge units is the only possible solution in terms of charge and symmetry conservation. Although a "virtual" lepton in terms of electric charge, the fully expanded (normal) baryon cannot undergo leptonic decay because of its explicit and conserved color charge (neutrinos do not carry color charge). If the quarks are fully compressed again, however, the color charge vanishes (the symmetry principle of "asymptotic freedom" - (Politzer, Gross, and Wilczek, 2004 Nobel Prize)) and this obstacle is removed. "Proton decay" can then go forward (via the "X" IVB) with the emission of a leptoquark neutrino. (See: "The Origin of Matter and Information".) (Because the gluon field is composed of color-anticolor charges in all possible combinations, it will sum to zero color and self-annihilate when sufficiently compressed - perhaps to leptonic size.)

We owe the stability of the proton to the unthinkable energy densities of the cosmic forge in which it was produced. Like Frodo's ring, the proton can only be destroyed in the furnace which created it. Nevertheless, proton decay may be commonplace today in the interiors of black holes. (See: "The Half-Life of Proton Decay and the 'Heat Death' of the Universe".)

Summary of the Leptonic Spectrum

In summary, the elementary leptonic particle spectrum consists of 3 known members, the electron, muon, tau, and a 4th (very heavy) hypothetical leptoquark, each with its own neutrino (and corresponding antiparticles). They form an energy-absorbing series, each useful at a particular energy density of the early Universe. The heavy leptoquark is the champion energy-absorber with its internal set of compressible quarks. The quark mass spectrum has even better energy-absorbing utility than the leptonic series. When, during the Big Bang, the leptoquark finds itself without an annihilation partner (due to the asymmetric decay of electrically neutral leptoquark-antileptoquark pairs - the fundamental weak force asymmetry), its quarks expand as the external pressures of the Big Bang are relieved by the expansion and cooling of the Cosmos (due to the entropy drive of free energy - light's intrinsic motion). Once the quarks have expanded under their mutually repulsive electrical and quantum mechanical forces, the conserved color charge becomes explicit and leptonic decay via the leptoquark neutrino is no longer possible - neutrinos do not carry and hence cannot cancel color charge. The game is over - the expanded leptoquark is trapped with no annihilation partner - it must leave its symmetric state in Heisenberg virtual reality and enter the 4th dimension of real time as a heavy baryon (hyperon), decaying in a downward "cascade" to its lowest energy state, the proton. As it descends in energy, it produces the elementary leptons (via the "W" IVBs) it needs to balance its leptonic unit of electric charge. Such decays are mediated by the IVBs, and they are the only way single leptons are produced as a permanent, net, reaction residue, which is why we find exactly one (net) electron for every (net) proton in the Universe. (See: "The Particle Table".) The leptonic field functions as an alternative charge carrier for the baryons, which otherwise could balance their electrical charges only with antimatter, causing annihilation reactions.

Baryons, Mesons, and Quarks (strong force)

The triumph of Nature's energy compaction mechanism is the baryon with its three quarks. In its primordial form this particle is the leptoquark. The model I use for the leptoquark is the "fractured" elementary lepton: baryons (and their precursors, leptoquarks) are elementary, leptonic particles which have been fractured into 3 parts under the great pressures of the initial energy density of the "Big Bang". The baryon is simply a leptoquark with its 3 quarks expanded and the color or strong force which binds them explicitly revealed. The compacted leptoquark is the highest energy member of the leptonic elementary particle spectrum, with its quarks so tightly compressed that the color charge is implicit, not yet exposed. Hence all particles (baryons and leptons) are leptonic or elementary in their origins, which is why they carry exactly the same unit charges and interact so freely. This is also why we anticipate the existence of leptoquark neutrinos - which in turn are likely "dark matter" candidates.

The "utility" of fracturing an elementary particle into three parts, or "quarks", is twofold: 1) it becomes possible to arrange the internal, partial electric charges of the quarks into an electrically neutral configuration, as in the neutron (electrical neutrality is an essential precondition for the symmetry-breaking production of matter in the "Big Bang"; 2) the fractured particle becomes a much better energy absorber, since its quarks can be compressed, soaking up energy like a set of internal springs. The entire leptonic spectrum of increasing mass (including the quark series) is primarily useful for its energy-absorbing and storage capacity at different stages of the Big Bang, when all the energy of the Universe was confined to a very small spatial volume: much better to store energy as particles rather than waves under these extremely spatially cramped conditions. In fact it seems likely that the Universe could not have begun as a singularity without such an inherent capacity to compactly package its enormous energy content. The particles absorb and dampen the violence of the initial blast (perhaps preventing damage to the dimensional structure of spacetime), just as the mass and inertial momentum of a mountain absorbs the energy of an underground nuclear explosion. Furthermore, massive particles produce a gravitational field of negative energy which exactly cancels their positive "rest mass" energy, allowing the Cosmos to be born in a state of zero net energy and charge (due to the presumed initial balance between matter and antimatter).

Massive particles can also store an unlimited amount of energy as momentum and kinetic energy, a feature of particular utility in preventing the formation of a cosmic black hole rather than a "Big Bang". Another rationale for mass is the benign character of the entropy drive of bound energy, time. Unlike the vitiating "velocity c" (the spatial entropy drive of free energy), the intrinsic motion of time ("velocity T" - the historical entropy drive of bound energy) does not readily dissipate the energy content of mass. Whereas light fully participates in the expansion and cooling of its spatial conservation domain, matter does not similarly participate in the expansion and decay of its historic domain of information (see: "The Time Train"). Matter formed in the Big Bang still contains almost all of its bound energy content, whereas light formed at the same time has cooled to nearly absolute zero, worthless for any work application. The Universe would be a dull place indeed if at least some of its energy content, in the beginning, had not been stored as mass or bound electromagnetic energy in atomic matter for future use. (See: "Spatial vs Temporal Entropy".)

Quarks

Quarks have a special significance, for without quarks there would be no material Universe. Ordinary leptons are produced and decay symmetrically in particle-antiparticle pairs. There is no escaping the annihilation reactions required by their opposite electric charges. But this is not true of particles containing quarks, because the quark combinations can sum to electrical zero, as in the neutron. This possibility provides an avenue of escape from the all-compelling electric charge, a window of time in which one member of a neutral leptoquark-antileptoquark pair can undergo a leptonic decay (similar to proton decay), leaving the other pair member without an annihilation partner. If the remaining partner does not also self-destruct immediately, its quarks will expand, the color charge will become explicit, and its neutrino, which cannot cancel color charge, will be unable to consummate a leptonic decay. The leptoquark is consequently trapped in time; its quarks will expand fully as the external pressure allows, and it will become a "real" high-energy baryon ("hyperon") rather than a virtual leptoquark. The hyperon so formed will decay in a "cascade" to the ground state proton (via the "W" IVB), producing electrons, mesons, and neutrinos as alternative charge carriers when necessary to balance the electric, color, or identity charges of the various intermediate products, stages, and interactants of the decay pathway. (See: "The Origin of Matter and Information"; see also: "The Higgs Boson and the Weak Force IVBs".)

Leptoquarks can undergo leptonic decay (with the aid of leptoquark neutrinos, the ambient pressure of the Big Bang, or via the "X" IVB) while their quarks are so tightly compressed that the color charge vanishes (the symmetry principle of "asymptotic freedom"). Protons can do the same if their quarks are compressed tightly enough (to "leptonic size"), summing their internal color field to zero, a process requiring enormous symmetrically applied pressure, probably available today only in the interiors of black holes (or via the weak force "X" IVB). The stability of the proton is a testament to the enormous pressures under which it (in the form of a leptoquark) was created.

As the high energy baryon (hyperon) decays to its ground state (the proton), it brings into existence (via the "W" IVB) something else that is unique - single leptons, whose electric charges (which of course are the same as the baryon's own leptonic charge), can be used to balance the proton's electric charge. Hyperon decay (including neutron "beta" decay) is the only pathway through which single, permanent, massive leptons can be created, which is why there is exactly one electron for every proton in the Universe (other reactions can produce single, charged leptons (as in meson or muon decays) but they are always balanced by antiparticles somewhere in the reaction chain, and so are not permanent).

Quark Confinement

The baryon's quarks must be permanently confined in a simple sense because the baryon is derived from an elementary leptonic ancestor and it must continue to exhibit a unit elementary or leptonic charge. The baryon must be a "virtual" elementary particle, in terms of charge, if it cannot be a "real" one. If the baryon were to actually fly apart, there is no available quantum unit of charge which could cancel, neutralize, or annihilate the partial, sub-elementary charges of its quarks, a disaster for symmetry conservation. The only solution is to permanently confine quarks to combinations which sum to whole quantum units of charge, the leptonic charge units. This task of confinement is accomplished by a field of force carriers called gluons, massless field vectors of the strong force which travel with intrinsic motion c, although wholly confined within the baryon. Thus we find that "keeping up appearances" is important even at the level of elementary particles.

The quark spectrum, like the leptonic one, is useful in a practical sense for absorbing energy. We do not know why it displays the particular pattern it does (3 "families" of paired quark "flavors"); in our present state of knowledge it is, and may remain, a "given condition" of our Universe. Certainly we can understand that these are resonant energy forms of one another, but that does not help us to understand why they display this pattern rather than some other. We have to accept the fact that we live in a conserved, organized Universe, and that in consequence we will observe order and pattern of some sort, but why that pattern has its particular form may not be explicable beyond Occam's principle of the simplest system sufficient for the task of primordial symmetry-breaking. Perhaps the most reasonable guess is that the three families of quarks and leptons are related to the three dimensions of space - the spatial metric is reflected in the particle metric, because particles are originally formed from an interaction between the energy of light, the structure of metric spacetime, and the combined action of the four forces of physics. In such a scenario, the simple leptons would be related to the time dimension and the much more complex quarks to the spatial dimensions. (It has also been suggested that the three "family" structure of the elementary particles is necessary (for technical reasons of quantum mechanics) to produce the asymmetry which characterizes the weak force decay responsible for the creation of matter during the "Big Bang".)

Gluons (field vectors of the strong force)

Gluons are the field vectors of the strong force. Gluons are massless, traveling between the three quarks of a baryon at velocity c. Each gluon is composed of a color x anticolor charge, which it carries from one quark to another. There are three "colors": red, green, blue, and corresponding anticolors (not real colors, just names of convenience). Each quark carries a color charge, which interacts with the color charges carried by the gluon. The interaction changes the quark color; the quark emits a new gluon, which carries a new color combination to another quark, changing its color, and so on ad infinitum. The constant interchange via gluons of color charges between quarks is the binding mechanism of the strong force. Almost all the mass of a baryon is due to the binding energy contained in the gluon field, not in the quarks themselves. (See: "Getting Your Quarks in a Row" by Brian Hayes; *American Scientist,* Nov.

- Dec. 2008, pages 450-454.) The standard model of the strong force ("quantum chromodynamics") was worked out by Gell-Mann and Zweig, Han and Nambu, and others, in the mid nineteen-sixties. See *Inward Bound* by A. Pais, 1986, Oxford, for a full recounting of these discoveries.

Conversely to the long-range "particle" forces, electromagnetism and gravitation, the strong force grows stronger with increasing distance rather than weaker, the type of force one experiences when stretching a rubber band. Although this type of force has an explanation in terms of a "round-robin" exchange of virtual gluons which are also attracted to each other, we can understand this force more easily from the point of view of symmetry conservation. As the quarks expand, their partial charges become more exposed to the outside world and hence become more of a threat to charge conservation (symmetry conservation), since (given the absence of antimatter) there is no quantum unit charge which can cancel, neutralize, balance, or annihilate the quark partial charges. Charge-symmetry conservation requires these partial charges to be kept close enough together that they effectively sum to whole quantum unit (leptonic) charge values - insofar as the long-range electrical force is concerned (the "outside world"). This requirement will define the limits of the spatial volume occupied by the baryon, and the maximum distance between quarks. Hence symmetry/charge conservation and quantum mechanical constraints both conspire to create the strong force, permanently confining quarks via a field of virtual gluons. The strong force gluons have exactly the character one would expect if an elementary particle were fractured into 3 parts, but nevertheless required to remain a "virtual" elementary entity in terms of whole quantum (leptonic) units of charge, as "seen" by the outside world (via the long-range electromagnetic force).

While the strong force, quarks, gluons, and color charges may seem very complex, they are undoubtedly the simplest system which is sufficient to break the symmetry of the primordial elementary (leptonic) particle-antiparticle pairs. Simply fracture an elementary leptonic particle into three parts so that its partial charges can arrange themselves into electrical neutrality, and the strong force must follow of necessity. This only sets the stage for symmetry-breaking however, and what is still not clear is how or why the weak force asymmetry is arranged - other than by the obvious requirement of the "Anthropic Principle" (the Universe must be so constituted that it allows our existence).

The most important aspect of the color charge is its composition. Gluons consist of color x anticolor charges in every combination; therefore the field in total sums to zero. The field can be physically summed up by forcing the quarks together. When the quarks are fully compressed, the original leptonic elementary particle is recreated and the need for the confining color charge vanishes (the limit of "asymptotic freedom" - Politzer, Gross, Wilczek: 2004 Nobel Prize in Physics).

It requires tremendous energy, symmetrically applied, to force the quarks together against their mutually repulsive electrical and quantum mechanical forces. It is just this resistance to compression that makes baryons such excellent energy-absorbers, and so useful for "packaging" and compactly storing the free energy content of the early Universe. (Other reasons for converting free electromagnetic energy to bound electromagnetic energy include the negative energy of gravity associated with mass, and the storage of energy in a form which is not subject to the vitiating entropy drive of free energy, as gauged by "velocity c".)

Proton Decay

When the quarks are fully compressed to "leptonic size", the color charge vanishes. This is the leptoquark configuration; the particle is now actually a heavy lepton with only an implicit color charge and it can undergo leptonic decay via the "X" IVB, with the emission of a leptoquark neutrino. During the Big Bang, such decays by electrically neutral anti-leptoquarks isolated their leptoquark partners whose quarks subsequently separated, producing heavy baryons (hyperons), and through their decay, the neutrons, protons, and leptons of the expanding and cooling Universe.

Gluons have been compared to "sticky light". They are no doubt aspects of the electromagnetic field, photons modified in some way to attract each other and the quarks. Gluons must have been produced during the partitioning of the compressed electromagnetic wave packet that comprised the mass of the original lepton. It is not hard to imagine that as these partitions (quarks) were pulling apart, each produced a particle-antiparticle charge pair (the three colors and anticolors of the gluon field), for reasons of symmetry conservation mentioned above (the quantum mechanical requirement for unit charges). Just as a baryon may be derived from a "fractured" elementary lepton, so a gluon may be derived from a "fractured" photon, splitting the field vector of the primordial leptonic electric charge (this is probably why gluons attract each other). Both the fractional charges of the quarks and the fractional gluon field vectors remain permanently hidden from view, as if Nature were ashamed of such trickery.

But how does one get a 3 component color field out of an electrical dipole? One of the colors (green) is apparently neutral, so the color field components can be represented (in terms of electrical analogs) as (+1, 0, -1), with the charges of the anti-colors reversed. Green-antigreen is completely neutral (0 x 0), leaving the 3 x 3 color x anticolor matrix with only 8 active gluons rather than 9, as is indeed believed to be the case. (See: "Proton Decay and the 'Heat Death' of the Universe".)

The Strong Force - Two Expressions (See: "The Strong Force: Two Expressions".)

The strong force has two structural levels of expression, quite different, one (discovered by Gell-Mann and Zweig, 1964) between quarks *within* the individual baryon (mediated by a gluon exchange field), and another (discovered much earlier by Yukawa, 1934) *between* individual baryons within a compound atomic nucleus (mediated by a meson exchange field). While the internal baryon level of the strong force consists of an interaction among three quarks carrying 3 "color" charges ("red, green, blue") exchanging a color-carrying gluon field, the strong force at the compound nuclear level consists of an interaction between two or more baryons carrying 2 quark "flavor" charges ("up, down"), exchanging a flavor-carrying meson field. The gluon field is composed of virtual color-anticolor charges, and the meson field is composed of virtual flavor-antiflavor charges, so the analogy is complete, except that the gluon field is massless while the meson field is massive. The massless gluon field nevertheless produces a short-range field because unlike photons, the gluons attract each other (gluons have been compared to "sticky light").

Two particle charges unique to the quarks, "flavor" and "color", each produce a version of the strong force, expressed at different structural levels of the nuclear material. The color version of the strong force is expressed within the baryon, producing absolute quark confinement, while the flavor version of the strong force is expressed between baryons in a compound atomic nucleus, producing a very powerful (but not absolute) binding of baryons within the nuclear boundary.

The role of the color charge is to protect charge invariance, charge conservation, and symmetry conservation by maintaining the integrity of whole quantum charge units, hence explaining the absolute character of the confinement of quark partial charges. The role of the flavor charge is also symmetry-keeping, but with respect to energy states rather than charge, a function with more "degrees of freedom" (since energy can be conserved in many forms, unlike charge.) The flavor charge contribution in the strong force meson exchange field is to reduce the amount of bound energy (mass) contained in the baryon ground state as far as possible, while not violating the absolute parameters of charge conservation (electric charge, color charge, baryon number charge, spin).

It is the fact that we have two ground state flavor charges (up-down), that allows us to have two ground state baryons (neutron and proton), which can share their virtual meson fields and so bond together by reducing their total bound energy content. Because neutrons spontaneously decay into protons (half-life of about 15 minutes), and protons, given a sufficient energy boost, will revert to neutrons, we see that these two particles are in a real sense simply differently charged versions of one another. This close "family" relationship (as demonstrated by these weak force transformations) is the basic reason why these particles can form a combined "resonance" or "superposition" - the "nucleon" (as demonstrated by strong force bonding).

Compound Atomic Nuclei

It is remarkable what a variety of compound atomic nuclei can be produced by the exchange of a simple meson particle-antiparticle pair between proton and neutron (92 natural elements plus hundreds of isotopes). Another remarkable fact is that it requires the input of gravitational energy (as in the stars) to force these nucleons into such close proximity that they will actually bond. They will not bond spontaneously (unlike the gluons), but require some additional external coercion. Hence the nucleosynthetic pathway conversion of bound to free energy is actually the role of gravitational symmetry conservation, not actually an "agenda" of the flavor charge, although we can see symmetry conservation as a role of their combination (flavor charge plus gravitational force). As we have seen, the gravitational force is produced by the time dimension or historical entropy drive of matter. Therefore, the stellar conversion of bound to free energy is ultimately a consequence of the temporal entropy drive of matter, eroding and vitiating the energy content of atoms via gravity. Entropy increase and symmetry conservation work hand in hand.

Flavor charges apparently exist to quantize and regulate, scale, or "gauge" the mass of the several types of quark. The function of quantized flavor charges is to ensure that the mass of quarks is invariant no matter when or where they may be created. The partial or fractional flavor charges of the quarks are not strictly conserved, whereas the "number" or "identity" charges of the leptons (including the leptoquark) are strictly conserved. Therefore we should not refer to leptonic charges as "flavor" charges, but as either "number" or "identity" charges. A (hypothetical) number charge is associated with the leptoquark (and carried in its "bare" form by a leptoquark neutrino), but no number or identity charges are associated with the sub-elementary quarks themselves (there are no neutrinos associated with individual quarks).

The color charge of the strong force clearly has an "agenda" of quark confinement in the service of symmetry and charge conservation, through the protection of whole quantum charge units. The flavor charge of the strong force also has a (less obvious) agenda of symmetry conservation, but not through charge conservation, rather through the release of bound to free energy by regulating the energetic mechanism of the nucleosynthetic pathway.

The miracle of the strong force (at the compound nuclear level) is of course the 92 elements of the periodic table (and their many isotopes). These exist only because the proton and neutron can coexist as a "doublet", a paired bound state of nuclear matter which achieves in its combined form (the "nucleon") a state of lower bound energy than either partner could alone. The origin of this miracle goes back to the paired quark families and the ground state "up, down" flavor pairs. Why do quarks come in paired families, anyway? The pairing phenomenon is also seen in the lepton families as they pair with neutrinos, and in the pairing of quark families with lepton families, of meson and gluon charge-anticharge pairs, of matter and antimatter, and even of space and time. The ultimate source of all this pairing is probably electrical, originating with the dipoles of both electric and magnetic fields in the primordial source of cosmic energy, light. When light interacts with the metric of spacetime to produce particles (during the Big Bang), the electromagnetic dipole of light, the tripole of space, and the quadrupole of spacetime are carried into the structural fabric of particles. (See: "Nature's Fractal Pathway".)

Nucleons

The "nucleon" is a combined state of both the proton and neutron, a resonance or superposition of these particles. Because in the combined state the baryons can share their load of "parasitic" virtual mesons, a significant reduction of their total bound energy is possible. This reduced energy is the "binding energy" of the atomic nucleus released in nuclear fusion. The quark composition of the proton is "uud+", while that of the neutron is "udd". The exchange of a (virtual) meson particle-antiparticle pair, u<u>d</u>+ or <u>u</u>d- (antiparticles underlined), changes a proton into a neutron and vice versa. If two protons and two neutrons combine, they can position themselves at the corners of a tetrahedron in which all partners are equidistant. In the tetrahedral configuration meson exchange is especially efficient, as each proton has two equidistant neutrons to play the round-robin exchange game with, and vice versa. This 4-baryon tetrahedron is the alpha particle or helium nucleus, an especially tightly bound and favored nuclear configuration (the "brick" of the nucleosynthetic pathway), and it is easy to see why. The exchange of mesons between neutron and proton is exactly the "sharing of differences" that epitomizes the third stage of the General Systems model. It leads directly to the 4x3 tetrahedral bonding of the alpha particle (4 nucleons each of 3 quarks), and thence to the carbon atom - 3 alpha particles each of 4 nucleons; and so on up the nucleosynthetic pathway in alpha particle increments. (See: "The Fractal Organization of Nature".)

The "nucleon" can also be imagined as a state of higher symmetry than either the proton or neutron alone - the analog of a force unification symmetry state, but expressed at the particle level. This symmetry state was originally given the name of "isospin" symmetry or "isotropic spin" symmetry, and was conceived as a global symmetry state for which meson exchange formed the local symmetry "current" or field vector, and the proton and neutron were the local derivatives.

"Isotropic spin" symmetry or "isospin" symmetry leaves the strong force unaltered when protons and neutrons are interchanged. The name derives from assigning a completely imaginary state of "spin" to the nucleon ("up" for the proton and "down" for the neutron). This theoretical spin state is isotropic (invariant) insofar as the strong force is concerned, whether it is in the up or down "phase". "Global" isospin symmetry was understood as a natural consequence of "local" strong force meson exchange between the nucleons. When the quark model was developed by Gell-Mann and Zweig, the "up" and "down" designations were retained for the ground state quark flavors. The superseded isospin model was then applied to the actual (rather than virtual) weak force transformations of neutrons to protons. The weak force is also a short-range force with massive field vectors, the IVBs. Also like the strong force, meson exchange occurs in weak force baryon transformations, but is mediated by the much more massive IVBs. (See: "The 'W' IVB and the Weak force Mechanism".) (See: Robert Oerter: *The Theory of Almost Everything*. Penguin (Plume) 2006.) (See: James Trefil: *The Moment of Creation*. Macmillian (Collier) 1983.)

The Miracle of Matter

Local gauge symmetry is epitomized in the neutral, quiescent nature of the cold, crystalline, ground state of atomic matter, the state we normally occupy that is so life-friendly. Because it is our normal, habitual state, we become thoroughly accustomed to it and forget how remarkable it really is. The heavy elements of which we are composed are very strange particles indeed: the nuclear material is composed of baryons containing 3 colored quarks confined by a massless gluon field exchanged at velocity c. Baryons in turn consist of two kinds, protons and neutrons, bound (in compound atomic nuclei) by a virtual meson field exchanged between baryons, which reduces them both to a common denominator of least bound energy - the androgynous "nucleon". This fantastically complex nucleus is in turn surrounded by a cloud of electrons bound to the nucleus (and each other) by a massless field of exchanged photons. These electric and magnetic fields will allow the creation of molecules and a further hierarchy of chemical structure, information, and complexity.

Nor is this all: these particles and fields are surrounded by (and engender) clouds of virtual particles which contribute to the interactions and total bound energy. Elementary particles carry various conserved charges such as electric, color, identity, and spin, including partially conserved charges such as the local quark "flavor" charges. There are neutrinos associated with each elementary particle (neutrinos function as alternative charge carriers for "identity" or "number" charge); and while all charges are balanced by alternative charge carriers rather than antiparticles, antimatter is abundantly present in the gluon and meson fields, and in the clouds of virtual particles. The photon is its own antiparticle. The whole atomic complex is set within the regulatory metric and entropic fields of spacetime and gravitation, and subject to the exotic transformation fields of the weak force IVBs which can create, destroy, or transform elementary particles, and elevate portions of the material system above the ground state of electromagnetic symmetry to a higher level of force unification (electroweak force unification or even the GUT symmetry level).

The incredible complexity of matter beggars our understanding, and yet in its ground state it is perfectly well behaved and predictable (in its gross characteristics), a benevolent condition necessary to our evolution and survival. The meson field of the strong force succeeds in reducing the energy level of most heavy atomic nuclei to a quiescent ground state. Radioactive decay is not a common phenomenon in our ordinary elements - one has to look rather hard to find it, as the Curies discovered. The local activity of the meson field provides us with a (mostly) non-radioactive spectrum of stable heavy elements capable of producing and sustaining life - which itself is a whole new level and hierarchy of chemical and biological information and complexity, built upon the electron shell and delicate bonding chemistry of carbon atoms and water molecules. At the top of this biological order, humans are building an entirely new information domain of abstract and symbolic thought patterns, imagination, languages, culture, and mechanical and technological systems, including "artificial" machine languages (computers) and communication networks (the internet). (See: "The Fractal Organization of Nature".) *(Go to: "The Short-Range or 'Particle Forces': Part II")*

Links:

Weak Force, Intermediate Vector Bosons ("IVBs")

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