Global and Local Gauge Symmetry in the "Tetrahedron Model": Part I

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Homepage
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PART I

Abstract

The phenomenon of "local gauge symmetry" is a ubiquitous and fundamentally important process in nature, essentially describing the normal activity of the field vectors of all four forces of physics. Although formidable in name, it is simple in concept: it comprises the process/mechanism of changing or protecting any conserved parameter of a *single* elementary particle. "Local gauge symmetry" is a necessary part of our world for two basic and interrelated reasons: 1) our universe is asymmetric in that it is formed of matter only, lacking a balancing antimatter counterpart; 2) our universe consists of an interacting mixture of a) free electromagnetic energy (massless light) in absolute "intrinsic" spatial motion at "velocity c", but with intrinsic rest in time; and b) bound electromagnetic energy (massive particles) at intrinsic rest in space but with an intrinsic temporal motion which is the metric equivalent of "velocity c". "Local gauge symmetry" activities in the short-range nuclear forces (strong, weak) are consequent upon 1); in the long-range spacetime forces (electromagnetism, gravity), such phenomena are consequent upon 2).

The bound forms (massive particles) of electromagnetic energy carry various conserved attributes (charge, spin, etc.) which are the *symmetry debts* of the free energy from which such particles are made: *the charges of matter are the symmetry debts of light* (Noether's Theorem). Conserving, protecting, and maintaining these charges in their original quantity and quality is a major function of the field vectors of the four forces and the "local gauge symmetry currents" they create, all to the end that the original symmetry and energy of the light or free electromagnetic radiation which initiated the universe will be completely conserved. Other issues of energy, entropy, and causality conservation are addressed by the metric properties of the long-range forces (such as the "Lorentz invariance" of Special

Relativity) - including, in the case of gravity, the "non-local" distributional symmetry of light's energy, as well as light's spatial entropy drive, both produced by light's intrinsic motion.

Preface

> 1) Noether's Theorem requires the conservation of light's symmetry no less than light's energy.
> 2) The charges (and spin) of matter are the *symmetry debts of light*.
> 3) Charge (and spin) conservation is a temporal, material form of symmetry conservation.
> 4) Maintaining and/or paying (conserving) light's symmetry debt is a major functional role and rationale of the 4 forces of physics (field vectors).
> 5) Charge invariance in time and space (in the service of symmetry conservation) is the key to understanding the local action of the forces ("local gauge symmetry").
> 6) The field vectors of the forces act via "local gauge symmetry currents" which maintain charge invariance despite relative motions or other variations in local conditions - serving charge and symmetry conservation, and in the case of gravity, serving energy, symmetry, entropy, and causality conservation (via "Lorentz Invariance", and because gravity creates time).
> 7) Gravity (as gauged by the universal gravitational constant "big G") transforms the global spatial metric of absolute motion and massless light, as gauged by the universal electromagnetic constant "c", into a local spacetime metric accommodating relative motion and massive matter, as well as light. (The local gravitational metric is characterized by "little g".) (Gravity creates time by the annihilation and conversion of space to its temporal metric equivalent.)
> 8) Gravity pays the entropy-"interest" on matter's symmetry debt, creating time by the annihilation of metrically equivalent space, decelerating cosmic expansion in consequence. Conversely, the gravitational conversion of bound to free energy (as in stars, quasars, and via Hawking's "quantum radiance" of black holes), pays the energy-"principle" on all symmetry debts, restoring (and hence to all appearances "accelerating") the original cosmic expansion. The radiance of our Sun and the stars represents a completed "circuit" of symmetry conservation. (See: "Currents of Entropy and Symmetry)".

"Local vs global gauge symmetry" is a technical subject which, in its full formal application, is far beyond this author's level of mathematical ability. Nevertheless, we very much need to understand some important physical concepts addressed by this topic, so I will define below my own usage of this term and concept, which may be at some variance (hopefully small) with the way these ideas are presented in the textbooks.

As I understand and use these terms and concepts in the papers on this website, "global gauge symmetry" refers to a symmetry which is universally expressed, and which is not affected by changes in the absolute magnitude of its significant variable - provided these changes are universally applied. The usual example given is the voltage of a closed electrical system. Examples I use are the value of "velocity c" (the entropy and symmetry gauge of light), and the magnitude of various charges - electric, color, and flavor. If the magnitudes of "velocity c" or electric charge were different from what they are, we wouldn't experience the difference, provided the difference was universal. Even moderate changes in the value of the universal gravitational constant ("big G") could not be detected in free fall or orbit (if external observations are excluded). It is only when the values are locally different from one place to another that we become aware of such changes - as an electrical shock or current, or as the "weight" we feel in our normal (on Earth's surface) gravitational relationship.

In the "local" case the value of "little g" varies from place to place and planet to planet (or equivalently, in accelerated motions of various magnitude, as per Einstein's "Equivalence Principle"). Because "G" determines, regulates, or "gauges" the spacetime metric, variations in the local metric ("g") pose a problem for globally invariant parameters dependent upon the metric (such as "velocity c", the "Interval", and causality). Nevertheless, due to a "local gauge symmetry current" involving the covariance of space and time in Einstein's Special and General Relativity (clocks run slow and meter sticks shrink in the direction of motion or in a gravitational field), the invariance of velocity c, the "Interval", and causality are upheld under all circumstances of local variation in "little g" and the spacetime metric ("Lorentz Invariance" in Special and General Relativity).

The truly "global" values and constants are all determined at the beginning of our Universe - the fact that we have a universe of matter rather than antimatter, the values of "velocity c" and the gravitational constant, the value of electric charge, Planck's constant, the weak force asymmetry parameter, etc. Once set, determined, or "gauged", these universal global constants never change. But all interactions after the "Creation Event" are "local" in character.

The issue (of global vs local gauge symmetry) becomes of crucial importance only because we live in a compound universe composed of free and bound forms of electromagnetic energy (light and matter), which interact with one another in global (universal) vs local terms, an interaction which usually requires some sort of flexibility in its contact parameters. The universal or "global" terms are charge and such constants of the light universe as velocity c, while the "local" terms are matter, time, and relative and variable motion rather than absolute and invariant motion. Because charges are the symmetry debts of light, and therefore charge conservation = symmetry conservation, the invariance of charge must be strictly protected, in "local" variable conditions as well as in "global" invariant environments. A moving electrical charge is the classic example of a globally invariant energy form in a relative and variable environment - how can the invariant magnitude of its symmetry debt (electric charge) be protected if its energy content and charge magnitude varies with its relative motion? This protection is afforded by the action of the charge's magnetic field, which varies in strength in direct proportion to the relative motion of the charge. The electric charge remains invariant because its associated magnetic field exactly compensates the effect of relative motion.

A magnetic field is our prototypical example of a "local gauge symmetry current" employed to protect the magnitude of a globally invariant charge or symmetry debt. Note that the magnetic field is an embedded feature of the electric field itself ("electromagnetism"). All "local gauge symmetry currents" (field vectors) are of this type, containing embedded secondary features of their primary fields, specifically addressing the problem of the interaction of globally invariant parameters with locally variable conditions - that is, they form a flexible connection between the invariant, global parameters of the light universe and the relative, variable, and local conditions of the matter universe - free electromagnetic energy vs bound electromagnetic energy (the spacetime dyad mentioned above is the gravitational analog). A little thought suggest that it could not be otherwise - only energy with this innate characteristic could produce our compound universe of light and matter. Sunshine - the common light of day - is another example, in this case produced by fusion energy and accelerated electric charges in the Sun. Electric charge remains invariant while the excess energy of acceleration is released as light and/or other forms of electromagnetic radiation. Here, electric charge and its field vector, the photon, work together as an embedded pair, maintaining charge invariance in a relative rather than an absolute environment. "Cherenkov radiation", synchrotron radiation, radar, medical x-rays, radio and TV, microwaves, are all related phenomena, produced by accelerated (or decelerated) electric charges.

It is worth noting here that it is only through such connections that these two intimately related domains of energy can interact at all, for reasons of energy conservation. For example, neutrinos are restricted to interactions mediated by gravity or the weak force IVBs - since they lack electric charge and hence also lack magnetic fields. "Dark matter" may be a form of energy which has only gravitational connections to matter. Gravity is the "connection of last resort" between light and matter - the ultimate glue holding the universe together and maintaining its energetic and dimensional unity.

Co-varying spacetime is a dimensional example of a "local gauge symmetry current" which mediates between the 2- and 3-D spatial ("global") realm of light and the 4-D historical ("local") domain of matter. Gravity produces matter's time dimension directly from space, creating a combined historical metric which allows the basic dimensional interaction of free and bound energy, equilibrating not only the compound metric of light and matter (historical spacetime), but the primordial entropy drives of free and bound forms of electromagnetic energy (the intrinsic motions of light and time). Time is the critical dimensional parameter which allows energy conservation in the realm of matter and relative motion, including matter's causal linkages as well as matter's historical entropy drive. The multiple energy-conserving functions of the time dimension are why all forms of bound energy (and only bound energy forms) must produce a gravitational field. Massless light is non-local, atemporal, and acausal, producing no gravitational field; massive matter is local, temporal, and causal, and produces a gravitational field - which creates its own time dimension via the annihilation and conversion of metrically equivalent space. (See: "Entropy, Gravity, and Thermodynamics".)

Gravity, which because of its dimensional activity and metric function is the most fundamental and general of the "local gauge forces", does not conform exactly to the electrical pattern, because unlike electric charge, the gravitational charge is monopolar rather than dipolar, and moreover, gravity represents both a symmetry and an entropy debt of light. It is this double conservation role of gravity that makes it such a confounding force, for although its entropy conservation role is immediately and universally expressed in the conversion of space to time (for any bound energy form, large or small), its symmetry conservation role is only apparent at high field strengths, when bound energy is returned to free energy (in our Sun for example). Electric charge has only a symmetry conservation role, which can be neutralized, if not completely satisfied, by any opposite charge carrier (not necessarily an antiparticle) - due to the dipolar character of electric charge. The symmetry debt of gravity, however, can only be fully satisfied by the complete conversion of matter to radiation - as in stars, quasars, and Hawking's "quantum radiance" of black holes - due to the monopolar character of gravitational charge (because gravity produces one-way time). The two (gravitational) processes are essentially the inverse of each other, causing a lot of confusion regarding the actual rationale for gravitation, which on the one hand converts space to time (at all field strengths), and on the other converts matter to light (only at high field strengths) - conserving both the entropy drive of light (immediately) and the non-local symmetric energy state of light (eventually). Time is the functional analog of the magnetic field (in the terms of local gauge symmetry), and whereas the flexible magnetic field protects the invariance of electric charge, in material systems flexible time protects the invariance of velocity c, the "Interval", and causality ("Lorentz invariance").

As we shall see below, similar considerations apply to the field vectors of the short range or "particle" forces: the strong force whose gluon field produces quark confinement and protects and maintains whole quantum units of charge, and the weak force in which the massive Higgs boson and the IVBs produce invariant, single elementary particles - exactly the same in every conserved parameter since the beginning of time (mass, charge, spin, etc.). The "payoff" for "local gauge symmetry" is the quiescent state of ordinary, cold, atomic matter, in which charge conservation is observed, velocity c remains invariant, energy conservation and causality are strictly obeyed, and matter interacts seamlessly with light despite the absence of antimatter, and despite the huge differences between the "local" asymmetric, variable, and relative domain of bound electromagnetic energy (matter), and the "global" symmetric, invariant, and absolute realm of free electromagnetic energy (light).

The charges of matter are the symmetry debts of light. The requirement of charge invariance in the service of charge and symmetry conservation is the key to understanding the local action of the field vectors of the four forces of physics ("local gauge symmetry currents").

Charge Invariance

The common factor or pivotal connection between my use of the notion of symmetry in the "Tetrahedron Model" and the mathematical formalism of the "Standard Model" is the idea of *charge invariance*. This notion is the rock to which both our systems are anchored: charge invariance is crucial to symmetry and charge conservation. Charges are invariant with respect to relative motion, entropy, age, or gravitational metric, protecting their symmetry conservation function. The charges (among other parameters) of elementary particles are quantized expressly to maintain their invariance and ensure they can be reproduced exactly, thereby protecting their conservation function. The case of electric charge and magnetism is paradigmatic: the magnetic field is the relativistic expression of the motion of an electric charge with respect to a stationary observer.

The magnetic field is an alternative form of electrical energy which encodes and energetically accounts for the relative motion of electric charge, but which does not change the magnitude of electric charge. The existence of the magnetic field allows the relative (rather than absolute) motion of electric charge, conserving charge invariance, and therefore accomplishes the translation between the global, invariant gauge symmetry of electric charge and the local gauge symmetry of individual charge carriers in relative motion. The local gauge symmetry is manifest as (for example) the electrical neutrality of (ground state) atomic matter, despite the large relative velocities of electrons in atomic orbits around the massive and essentially stationary protons.

Because of the compensating action of magnetic fields, and the special quantum-mechanical rules that apply to electrons in atomic orbits, local leptonic charges in relative motion have the same magnitude as the "stationary" proton charge, and as the global, universal value of electric charge everywhere - a fact we ordinarily take for granted. We have the magnetic field (and laws of quantum mechanics) to thank for the local phenomenon of electrically neutral, charge-balanced, quiescent atomic matter and chemistry (including biochemistry and life), and for the relative ease with which free electromagnetic energy (light) interacts with matter (bound electromagnetic energy).

The smooth translation from global electrical gauge symmetry to local electromagnetic gauge symmetry depends upon the fact that light is an electromagnetic wave and that the photon is the field vector of electric charge. Thus from the beginning, the magnetic field is part of the electrical phenomenon (including the electrical field vector, maintaining the electrical neutrality of light), always ready to act in defense of the invariant value of electric charge, charge conservation, and hence symmetry and energy conservation. The magnetic field acts as the "local gauge symmetry current", maintaining the invariant magnitude of massive electric charges in relative motion. Here we see that a portion of the electromagnetic field vector is "split out" to serve as the local gauge symmetry compensatory current, a notion which we can also apply to the binding principle of the gluon field of the strong force, apparently also a subdivision of the original electromagnetic field vector (gluons have been aptly called "sticky light" - because they attract each other). Gluons are the strong force analog of a magnetic field, maintaining whole quantum unit charges ("quark confinement") despite an environment of moving, fractional charges.

We furthermore take note of the fact that the photon is its own antiparticle, an internal or self-symmetry which is also found in the field vectors of all the other forces, either individually (as in the graviton), or as a group (in the IVBs of the weak force, and in the gluon field of the strong force). This is an important factor enabling the field vectors of the forces to translate a global symmetry into a local one - especially evident in the action of the gluon field of the strong force, where "anticolor" is used to attract and cancel "color", so the transformation to a new color can occur. (Gluons are composed of color-anticolor charges in all combinations. In the case of the weak force IVBs, it is virtual particle-antiparticle pairs which become alternative charge carriers (leptons, neutrinos, mesons), facilitating particle decays and transformations. See: "Global and Local Gauge Symmetries in the Weak Force"; see also: "The "W" IVB and the Weak Force Mechanism".)

Noether's Theorem

The concept of symmetry in physics is founded upon a great mathematical theorem formulated by Emmy Noether (in 1918), which states that in a continuous multicomponent field, such as the electromagnetic field of light, or the metric field of spacetime, where one finds a symmetry one will find an associated conservation law, and vice versa. Hence the conceptual and unifying power of symmetry in physics derives from its intimate association with conservation laws. The mathematical field which addresses this association is known as "Group Theory". (See: Neuenschwander, Dwight E. *Emmy Noether's Wonderful Theorem*. 2011. The Johns Hopkins University Press.)

Noether's Theorem states (in essence) that the symmetry of light must be conserved, no less than its raw energy. We have two outstanding examples of Noether's Theorem enforced in everyday experience: 1) charge conservation; 2) the inertial forces of the spatial metric. My own synopsis of Noether's theorem is: "*the charges of matter are the symmetry debts of light*". Charge conservation (including spin) = symmetry conservation (symmetry as transferred from light and virtual particle-antiparticle pairs to a conserved form in massive elementary particles composed only of matter). Charges must retain their invariant, absolute values regardless of entropy, relative motion, gravitationally variable metrics, alternative charge carriers, or the expansion (or contraction) of the universe. Otherwise, charges will not be able to cancel, balance, or annihilate each other upon demand, and charge conservation, symmetry conservation, and energy conservation will all fail: the Universe would default upon its symmetry debt.

The field vectors of the charges (the local symmetry "currents") all operate in some way to maintain the invariant, absolute value of charge, despite the variable, relative environment of matter. For electric charge, this compensating factor in the field vector is the magnetic field of the photon; for the "location" charge of gravity it is the time component of spacetime; for the "identity" charge of the weak force it is the mass of the IVBs (necessary to reproduce the original energy density of the "Big Bang" in which elementary particles were formed); and for the strong force color charge it is the gluon field with its peculiar force law, which gets stronger with distance, producing the permanent confinement of the partial charges of quarks to particles (baryons and mesons) which display only whole quantum unit charge values.

The usual electrical neutrality of the (low temperature) atomic realm, established through balancing charges, is an expression of the local gauge symmetry of individual carriers of electric and magnetic forces, despite the fact that the atomic realm is constantly in a state of relative motion (electron orbits, gluon exchange between quarks, thermal agitation, quantum excitations, gross relative motions, etc.) - and consists of alternative charge carriers which are not the antiparticles of their charge-balancing partners (the electron-proton pair is the common example).

Time - like magnetism - is a "local gauge symmetry current", in both Special and General Relativity. Causality, velocity c, Einstein's "Interval", and energy and symmetry conservation, are all invariant principles requiring the protection of the flexible time dimension when massive particles and relative motions are involved. Electric charge, velocity c, and symmetry conservation are invariant principles requiring protection in the case of magnetism and the electromagnetic force. Time is necessary to conserve matter's energy accounts because of matter's relative (rather than absolute) motion, and time is also necessary to conserve matter's causality and "Interval" for the same reason. Time is furthermore the critical dimension for long-term charge conservation (charges, in the absence of immediate matter-antimatter annihilations, may be "stored" indefinitely in the temporal dimension until the debt is retired by charge annihilation with antimatter). Finally, the intrinsic motion of time is the primordial entropy drive of bound energy, creating and expanding history, the conservation domain of matter's causal information "matrix".

Gravity pays the "entropy-interest" on the symmetry debt of matter by creating time via the annihilation of metrically equivalent space, decelerating light's cosmic spatial expansion to fund matter's cosmic historical expansion. Gravity pays the "energy-principle" on matter's symmetry debt through the conversion of gravitational energy to light in quasars, by the conversion of bound to free energy in the nucleosynthetic pathway of stars (partially), and via Hawking's "quantum radiance" of black holes (completely).

In the case of the weak force, the invariance of several conserved parameters (charge, spin, mass, etc.) of elementary particles over time and space is the global symmetry which must be observed. The spacetime metric (the "vacuum") maintains this symmetry for the creation of particle-antiparticle pairs; but because the weak force only creates, destroys, or transforms *single* elementary particles (not particle-antiparticle pairs), the huge mass of the IVBs is necessary to recreate the primordial metric and energetic conditions of the "Big Bang" in which these particles were first created.

Each of the four forces of physics is associated with a specific charge. ("Charge" can be regarded as a type of energetic asymmetry (representing a broken symmetry of light in its temporally conserved form) from which the associated force acquires its characteristic activity.) My method of unification (in the "Tetrahedron Model") is simply to show how these charges correspond to broken symmetries of light (broken originally when light is converted into matter or bound energy during the Big Bang). This simple method leads to a qualitative understanding of how the forces are unified (they all originate as "symmetry debts" of light), and why they behave as they do (to restore the symmetric energy state of light - as per Noether's Theorem). It is not a quantitative, mathematical understanding, but because it is firmly based upon Noether's Theorem and the physical principles of natural law - energy conservation, symmetry conservation, entropy, and causality - I expect it could be reformulated mathematically into a fully consistent and formal statement of the Unified Field Theory. (See: "The Tetrahedron Model".)

The original understanding gained through the development of the "Tetrahedron Model" is now considerably enlarged by the addition of the principle of *charge invariance* as developed in the "global vs local gauge symmetry" theories of the "Standard Model". This marriage between the "alternative" "Tetrahedron Model" and "establishment" physics is a union which is possible only because both models are based squarely upon the same conservation laws. (See: "The 'Tetrahedron Model' vs the 'Standard Model' of Physics: A Comparison".)

For a more detailed discussion of "local gauge symmetry currents" in each of the four forces: Go to PART II

Go to PART III: POSTSCRIPT

Links

Unified Field Theory

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Symmetry Principles of the Unified Field Theory (a "Theory of Everything") - Part 2
Symmetry Principles of the Unified Field Theory (a "Theory of Everything") - Part 3 (summary)
Principles of the Unified Field Theory: A Tetrahedral Model
(Postscript and Commentary on paper above)
Synopsis of the Unification Theory: The System of Spacetime
Synopsis of the Unification Theory: The System of Matter
Light and Matter: A Synopsis
Global-Local Gauge Symmetries and the "Tetrahedron Model" (part I)
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Global-Local Gauge Symmetries and the "Tetrahedron Model":Postscript
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Gravitation

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The Double Conservation Role of Gravitation: Entropy vs Symmetry
12 Summary Points Concerning Gravitation
Extending Einstein's "Equivalence Principle"
The Conversion of Space to Time
"Dark Energy": Does Light Produce a Gravitational field?

Entropy

Section VII: Introduction to Entropy
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Spatial vs Temporal Entropy
Currents of Symmetry and Entropy
The Time Train
The Halflife of Proton Decay and the 'Heat Death' of the Cosmos

Weak Force, Intermediate Vector Bosons ("IVBs")

Section IV: Introduction to the Weak Force
The "W" Intermediate Vector Boson and the Weak Force Mechanism (pdf file)
The "W" IVB and the Weak Force Mechanism (html file)
Global-Local Gauge Symmetries of the Weak Force
The Weak Force: Identity or Number Charge
The Weak Force "W" Particle as the Bridge Between Symmetric (2-D) and Asymmetric (4-D) Reality
The Strong and Weak Short-Range Particle Forces
Section XVI: Introduction to the Higgs Boson Papers
The "Higgs" Boson and the Spacetime Metric
The "Higgs" Boson and the Weak Force IVBs: Part I
The "Higgs" Boson and the Weak Force IVBs: Parts II, III, IV
"Dark Matter" and the Weak Force

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"Trance, Art, Creativity" An Investigation of the Numinous Element and the Metaphysical Realm. A Book by Prof. John C. Gowan, Sr.
"Operations of Increasing Order" Further Investigations of the Numinous Element and the Metaphysical Realm. A Book by Prof. John C. Gowan, Sr.
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