Three-Element Theory of Nature

T. X. Zhang

Department of Physics, Chemistry, and Mathematics, Alabama A&M University, 4900 Meridian Street, Huntsville, Alabama.
E-mail: tianxi.zhang@aamu.edu

According to the newly well-developed four-element theory, nature consists of four fundamental elements, which are radiation, mass, electric charge, and color charge. Mass and radiation are two forms of real energies, while electric and color charges are two forms of imaginary energies. Considering that radiation and mass are dependent because they can be converted into each other via particle-antiparticle annihilations and pair productions, we can define a radiation photon, thought it is massless, an equivalent mass via dividing its energy by the square of light speed. This effort simplifies the new four-element theory to a simpler three-element theory. Along with the recently developed two-flavor multi-excitation model of quarks, we describe our universe to be a system of complex energy, be composed of three fundamental elements, be built up with two building blocks of up and down quarks, and be governed by four real forces between like energies and two imaginary forces between unlike energies. The four real forces are the well-known observable fundamental interactions (i.e. the gravitational, electromagnetic, weak, and strong interactions). The two imaginary forces are non-observable forces that explain why electric and/or color charges are adhesive, gluing or sticking on masses to form charged particles. This paper describes details of the three-element-theory.

1 Introduction

Recently, the author has developed a new four-element theory of nature [1]. It suggests that nature consists of four fundamental elements, which are radiation (γ), mass (M), electric charge (Q), and color charge (C). Any known particle observed in nature or discovered in labs is a combination of one or more of the four fundamental elements. Considering that mass and radiation are two forms of real energy, the author has analogically defined electric and color charges to be two forms of imaginary energy [2, 3]. This allows him to classically unify all fundamental interactions in nature into a single interaction between complex energies. Interactions between real energies are the gravitational field force with three categories: mass-mass, mass-radiation, and radiation-radiation interactions. Interactions between imaginary energies are the gauge field force with also three categories: the electromagnetic interaction between electric charges, the strong interaction between color charges, and the weak interaction between electric and color charges. The weak interaction as an interaction between electric and color charges is an innovative idea. Interactions between real and imaginary energies are imaginary forces, which have no direct observational support but can be used to explain why charges are adhesive and sticked on masses to form charged particles.

Based on the new four-element theory of nature, the author further developed a new two-flavor (up and down) multi-excitation (ground and excited states) model of quarks [4–6]. A quark is a composite of mass, electric charge, and color charge, so that the weak interaction between electric and color charges occurs within a quark and causes the quark to excite and decay. A quark changes its state from one to another via absorbing or emitting a quark-antiquark pair. Beta decays of nuclei/particles result from quark-antiquark pair emissions and annihilations. Leptons are products of decays rather than participants of weak interactions in the decays. The entire process of a beta decay involves all electromagnetic, weak, and strong interactions. A quark in a hadron does not change its flavor from one to another, but can be replaced by another quark with a different flavor. In this new quark model, the traditional heavy flavor quarks, such as the charm (c), strange (s), top (t), and bottom (b) quarks, are treated as the second and third excited states of up and down quarks: u_2, d_2, u_3, and d_3. Combinations of quarks and antiquarks form up to eight types of particles via different levels of annihilations. Combinations of three or more quarks and antiquarks can form normal and exotic baryons and probably candidates of dark matter particles such as hexaquark [7] and nonaquark [8].

This paper considers that radiation and mass are not independent. They can convert from one to another. In an electron-positron annihilation process, masses of electron and positron are converted to radiation energies of gamma ray photons. In a pair-production process, a massless radiation photon or gamma ray is materialized into a pair of electron and positron with masses. Defining an equivalent mass for a massless radiation photon via dividing its energy by the square of light speed, we can simplify the new four-element theory to a simpler three-element theory. This reduces the gravitational interaction to have the single category between masses, and makes our universe to be a system of complex energies (one real and two imaginary), composed of three fundamental elements (mass, electric charge, and color charge),

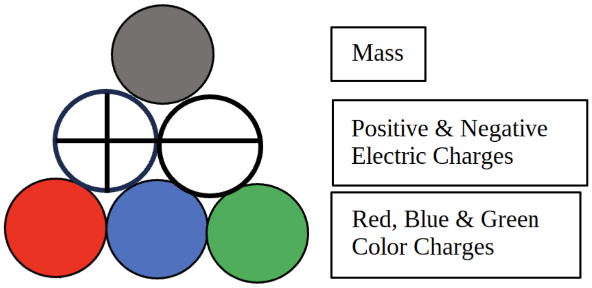

Fig. 1: Three fundamental elements of nature. They are mass, electric charge, and color charge. Mass is a form of real energy. Electric and color charges are two forms of imaginary energy.

Table 1: Three fundamental elements of nature: mass (M), electric charge (Q), and color charge (C). Any known particle is a combination of one or more of the three fundamental elements.

Particles/Elements	M	Q	C
Neutron	✓		
Weyl Fermion		✓	
Gluon			✓
Proton	✓	✓	
Massless Meson		✓	✓
Quark	✓	✓	✓

built up with two building blocks (up and down quarks), and governed by six fundamental interactions, in which the four real interactions are the well-known and observable four fundamental forces — the gravitational, electromagnetic, weak, and strong interactions — and two imaginary interactions are non-observable forces that play the roles in sticking charges on masses. This paper describes the three-element theory of nature in details.

2 Fundamental elements of nature

The three-element theory of nature suggests that nature consists of only three fundamental elements, which are mass (M), electric charge (Q), and color charges (C) as shown in Fig. 1. Any known matter or particle observed in nature or generated in labs is a combination of one or more of the three fundamental elements. For instance, as shown in Table 1, a neutron has mass only; a Weyl fermion has electric charge only [9]; a gluon has color charge only; a proton is a combination of mass and electric charge; a massless meson is a combination of electric and color charges; and a quark is a combination of mass, electric charge, and color charge. Furthermore, we can categorize the three fundamental elements as two types of energies. Mass is a form of real energy, while pure electric and color charges are two forms of imaginary energies.

2.1 Mass — a form of real energy

Mass is a fundamental property of matter. Mass of an object refers to the quantity or amount of matter that the object contains. According to Newton's gravitational law, the gravitational force between two objects is proportional to the product of their masses and inversely proportional to the square of distance between them. In physics, mass of an object is defined as a measure of its inertia. According to Newton's second law of motion, an object accelerates when a non-zero net force is applied on it. The acceleration is proportional to the net force applied and inversely proportional to the mass. According to Mach's principle of equivalence, the gravitational mass and the inertial mass are equivalent. We cannot tell the difference between sitting at rest in a gravitational field and moving with an accelerating frame. A body experiences an inertial force when it accelerates relative to the center of mass of the entire universe. Mass in the universe over there can affect inertia of an object around here. From Einstein's energy-mass expression, mass is also understood as a form of real energy. A particle at rest with mass M has a real energy, given by [10]

$$E_M = Mc^2, \quad (1)$$

where c is the speed of light in the free space. According to Einstein's special and general theories of relativity, spacetime is relative and affected by both motion and mass of an object. A particle in motion has an effective mass that is the rest mass times a Lorentz factor, which increases with the speed of motion. This real energy is always positive and measurable. According to the law of energy conservation, the energy of mass cannot be destroyed or created but can be converted from one form to another. In nuclear fission and fusion processes, the total mass may decrease or miss. The missing masses are converted into nuclear energy. From Einstein's energy-mass relation (1), a small amount of missing masses can be converted into a huge amount of nuclear energies.

Any particle, except for a radiation photon, has mass. Radiation refers to the electromagnetic waves, consisting of varying electric and magnetic fields, and can travel through vacuum itself at the speed of light, about 300 million meters per second. According to the increasing order of frequency or the decreasing order of wavelength, scientists usually categorize electromagnetic waves into radio wave, microwave, infrared, visible light, ultraviolet, X-ray, and gamma ray. Oscillations of electrons and nuclei including protons produce radio waves and microwaves; thermal motions of electrons and ions produce infrared light; orbital or energy changes of electrons in atoms emit visible light and ultraviolet; sudden stops of high-speed electrons on targets produce X-rays; and nuclear reactions and decays produce gamma rays. Light looks like a ray as it travels straightly. Isaac Newton believed light to be a particle because of its reflection and refraction. Thomas Young suggested light to be a wave because of its interference and diffraction. James Clerk Maxwell recognized light to be electromagnetic waves because they travel at the same speed. In quantum physics, radiation is quantized and described as radiation photons, which are massless quanta of real energy. The energy of a photon is given by $E_\gamma = h\nu$, where h is the Planck constant and ν is the radiation frequency [11]. Radiation quanta or photons of light explain blackbody radiation spectra, atomic emission and absorption spectra, Compton photon-electron scattering, and photoelectric effects.

In general, we can say that radiation is also a form of real energy and always positive. An atom, when it changes its state or energy level from one to another, emits a photon with frequency or energy given or determined by the energy difference. Annihilations between particles and antiparticles including quarks and antiquarks produce pairs of gamma rays. In a pair-production process, a gamma ray is materialized into a pair of particle and antiparticle with non-zero masses. Annihilations and pair productions indicate that the two forms of real energies (i.e. mass and radiation) can convert from one to another, so that they are not independent. We define an equivalent mass for radiation to be $M_\gamma = h\nu/c^2$. Thus, we can consider that nature is composed of only three fundamental elements: mass, electric charge, and color charge, rather than four, so that reduces the four-element theory of nature recently developed to a three-element theory of nature focused by this paper.

2.2 Electric charge — a form of imaginary energy

Electric charge is another intrinsic fundamental property of matter or some particles. According to Coulomb's law, the electric force between two electrically charged objects is proportional to the product of their electric charges and inversely proportional to the square of the distance between the two objects. Electric charges have two varieties: positive or negative. They appear always in association with masses as observed positive or negative electrically charged particles with different masses such as electrons and protons. The interaction between electric charges, however, is completely independent of their masses. Positive and negative charges can annihilate or cancel out each other and produce in pair with total electric charges conserved. A Weyl fermion is a massless electron, which was predicted a century ago and recently measured in semimetals but not individually [9, 12].

A pure or individual electric charge should have its own meaning in physics. Zhang [2] first hypothesized or considered electric charge Q to be a form of imaginary energy. The amount of imaginary energy is defined to be proportional to the electric charge as

$$E_Q = \frac{Q}{\sqrt{G}}\,c^2, \qquad (2)$$

where G is the gravitational constant. This expression (2) with a factor of $1/\sqrt{G}$ allows him to unify Newton's law of gravitational force with Coulomb's law of electric force into a single expression between complex energies of electrically charged particles [2]. The imaginary energy has the same sign as the electric charge. Then, for an electrically charged particle, the total energy is

$$E = E_M + iE_Q = (1 + i\alpha)Mc^2, \qquad (3)$$

where i is the imaginary number and α is the charge-mass ratio of the particle, defined by

$$\alpha = \frac{E_Q}{E_M} = \frac{Q}{\sqrt{G}M}\,, \qquad (4)$$

in the CGS electrostatic unit system. The complex conjugate of the energy of a charged particle such as an electron, $E^* = (1-i\alpha)Mc^2$, gives the energy of its corresponding antiparticle such as a positron [13].

Eq. (3) modifies Einstein's mass-energy relation (1) with electric charge to be expressed as an imaginary mass or energy. The absolute value of charge-mass ratio α is a big number for a charged particle. This implies that an electrically charged particle contains much more imaginary energy than its real energy. For instance, $\alpha = 10^{18}$ for a proton and $\alpha = -2 \times 10^{21}$ for an electron. A neutral particle such as a neutron, photon, or neutrino has only real energy. Weinberg [14] suggested that electric charges come from the fifth-dimensional space, which is a small compact circle space according to the Kaluza-Klein (KK) theory [15–17] that unifies Einstein's general relativity and Maxwell's electromagnetism into a five-dimensional spacetime. Zhang [18] has developed a five-dimensional fully covariant KK-theory with a scalar field and shown that electric charge and scalar field can affect light such as electric redshift for quasars [19] and gravity such as gravitational field shielding for supernova explosions [20].

An antiparticle has energy, simply obtained by conjugating the energy of the corresponding particle. A particle and its antiparticle have equal real energy but imaginary energy with opposite sign. In a particle-antiparticle annihilation process, their real energies completely convert into radiation photon energies and their imaginary energies annihilate or cancel out. In a particle-antiparticle pair production process, a radiation photon transfers its energies into masses or rest energies with a pair of imaginary energies, which combine with the masses or rest energies to form a pair of particle and antiparticle. Real energy is continuous, while imaginary energy is quantized. Each electric charge quantum e (or proton's charge) has imaginary energy about $E_e = ec^2/\sqrt{G} \sim 10^{27}$ eV about 10^{18} times greater than proton's real energy ($\sim$ 931 MeV). This ratio is about the ratio between the radius of proton and the radius of the circular fifth-dimensional space.

2.3 Color charge — a form of imaginary energy

Color charge C is an intrinsic fundamental property of quarks and gluons, related to the strong force [21]. It has analogy to the electric charge of particles, related to the electromagnetic force. In the standard model of particle physics, quarks have six flavors: up (u), down (d), charm (c), strange (s), top (t), and bottom (b); three colors: red (r), blue (b), and green (g); and fractional electric charges: $2e/3$ for the up-type quarks (u, c, t) and $-e/3$ for the down-type quarks (d, s, b). In the author's recently developed two-flavor multi-excitation quark model, quarks have only two types or flavors (u and d) but multiple excitation states (i.e. $u_0, u_1, u_2, u_3, \ldots,$ for the up quark and $d_0, d_1, d_2, d_3, \ldots,$ for the down quark). An antiquark's color is anti-red ($\bar{r}$), anti-blue ($\bar{b}$), or anti-green ($\bar{g}$). Its fractional electric charge has an opposite sign of its corresponding quark. An elementary particle is usually composed of two or more quarks or antiquarks and colorless with electric charge to be a multiple of e or neutral. For instance, a proton is composed of two up quarks and one down quark ($u_0u_1d_0$); a neutron is composed of one up quark and two down quarks ($u_0d_0d_1$); a pion meson π^+ is composed of one up quark and one antidown antiquark ($u_1\bar{d}_1$); a charmed sigma Σ_c^{++} is composed by three up quarks ($u_0u_1u_2$); and so on.

In analogy to the electric charge Q, Zhang has hypothesized or expressed the color charge C to be another form of imaginary energy. The amount of imaginary energy in a color charge is defined by

$$E_C = \frac{C}{\sqrt{G}}\,c^2, \tag{5}$$

in order to unify all fundamental interactions into a single interaction between complex energies [1, 3]. A quark with mass M, electric charge Q, and color charge C, has a total energy to be

$$E = E_M + iE_Q + iE_C = (1 + i\alpha + i\beta)\,Mc^2, \tag{6}$$

where the constant β is defined by

$$\beta = \frac{E_C}{E_M} = \frac{C}{\sqrt{G}M}\,. \tag{7}$$

Total energy of an antiquark can be obtained by conjugating the total energy of its corresponding quark, $E^* = (1 - i\alpha - i\beta)\,Mc^2$. A quark and its corresponding antiquark have the same real energy and equal amount of imaginary energy but their signs are opposite. The opposites of red, blue, and green charges are anti-red, anti-blue, and anti-green charges.

The color charge neutrality is a fundamental principle in quantum chromodynamics (QCD) stating that all observable, free-existing particles or hadrons (mesons and baryons) must have a net zero color charge. A meson is a composite of a quark and an antiquark, so that we have that the sum of red and antired, blue and antiblue, green and antigreen are all zero, $r + \bar{r} = 0$, $b + \bar{b} = 0$, and $g + \bar{g} = 0$. A baryon is a composite of three quarks, so that we have that the sum of red, blue, and green is zero, $r + b + g = 0$, An antibaryon is a composite of three antiquarks, so that we have that the sum of antired, antiblue and antigreen is equal to zero, $\bar{r} + \bar{b} + \bar{g} = 0$. Mathematically, color charge is described by the representation theory of the SU(3) group, where color neutral particles belong to the singlet representation. The color confinement refers to particles with colors or anticolors cannot be observed alone.

2.4 Energy space of particles

Using the three fundamental elements or energy components (M, Q, and C) as three axes of coordinates, we can construct a three-dimensional (3D) energy space for particles (Fig. 2). Any particle has a position or can be located in this 3D energy space with coordinates (M, Q, C) with $M > 0$. For instance, a neutral particle such as a neutron or a neutrino, including a radiation photon when it is equivalent to mass, has a coordinate $(M, 0, 0)$, located on the M-axis; an electrically charged particle such as a proton or an electron, is located in the M–Q plane with a coordinate $(M, Q, 0)$; and a quark has a position in the 3D space with non-zero coordinates. Weyl fermions are on the Q-axis and gluons are on the C-axis. And so on for many other particles, including antiparticles, we can locate each of them with a unique set of coordinates in this 3D energy space of particles. As the mass element is always positive, the energy space is actually two and a half dimensions (i.e. 2.5D).

The real and imaginary energies are conserved, respectively. In an isolated system, their total real energy and imaginary energy remain the same. The three energy components are independent and hence they cannot convert from one to another. Each energy component is conserved. The real energy is always positive. It cannot be created or destroyed but can be converted to other types of real energies and doing work. In a nuclear fission or fusion reaction, nuclear energy or energy of mass that is missed can be converted to heat, radiation, and kinetic energy. In an electron-positron annihilation process, mass is converted into radiation. In the pair production of a gamma ray, radiation is converted or materialized into masses. Being both negative and positive for electric charges and both color and anti-color for color charges, an imaginary energy can be canceled out or neutralized. Net charges in an isolated system remain the same. All the forms of real energies are not independent and can be converted from one to another. Here, we believe that the two forms of imaginary energies (electric and color charges) are independent and cannot convert from one to another, but they can interact via the weak force.

3 Fundamental interactions and unification

3.1 Fundamental interactions in nature

Fundamental interactions in nature are interactions among fundamental elements. Among the three fundamental elements, there are six (four real and two imaginary) fundamental interactions, see Table 2. The real force ($\vec{F}_{MM}$) is an

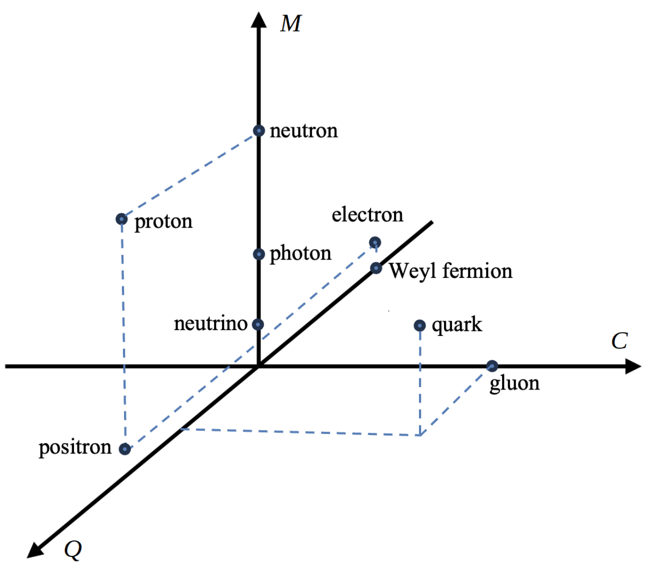

Fig. 2: A sketch for the 3D particle energy space. A neutral particle such as a neutron or a neutrino including a radiation photon is located on the M-axis, a Weyl fermion is located on the Q-axis, a gluon is located on the C-axis, an electrically charged particle such as proton or electron is located in the M–Q plane, and a quark is located in the 3D space with non-zero coordinates.

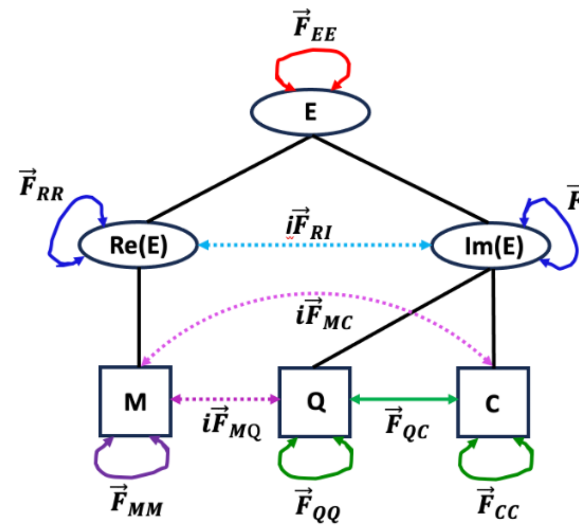

Fig. 3: Fundamental interactions among the three fundamental elements of nature: mass, electric charge, and color charge. Mass is real energy, while electric and color charges are imaginary energies. Nature is a system of complex energy, and all the fundamental interactions of nature are classically unified into a single interaction between complex energies. There are four real and two imaginary interactions among the three fundamental elements.

Table 2: Six fundamental interactions among the three fundamental elements.

Elements/Interactions	M	iQ	iC
Mass (M)	$\vec{F}_{MM}$	$i\vec{F}_{MQ}$	$i\vec{F}_{MC}$
Electric Charge (iQ)		$\vec{F}_{QQ}$	$\vec{F}_{QC}$
Color Charge (iC)			$\vec{F}_{CC}$

interaction between real energies (or masses), belong to the gravitational force. Another three real forces ($\vec{F}_{QQ}$, $\vec{F}_{QC}$ and $\vec{F}_{CC}$) are interactions between two forms of imaginary energies (electric and color charges, i.e. Q and C) and belong to the gauge field forces, named, respectively, the electromagnetic, weak, and strong forces. The two imaginary forces ($i\vec{F}_{MQ}$ and $i\vec{F}_{MC}$) are interactions between real and imaginary energies and have no direct measurements. Although these imaginary forces are not directly observational, they may play key roles in explaining why electric charges are always attached along with masses and absorb/emit radiation photons, and why gluons are adhesive. In physics, the fundamental interactions found in nature conventionally refer to the four real forces: gravitational, electromagnetic, weak, and strong forces.

3.2 Unification of all fundamental interactions

All the six fundamental interactions among the three fundamental elements (one real energy and two imaginary energies) can be classically unified into a single interaction between complex energies as given by the following equation or shown by Fig. 3 [1,3]

$$\vec{F}_{E_1E_2} = -G\,\frac{E_1E_2}{c^4r^2}\,\hat{r}\,, \tag{8}$$

where G is the gravitational constant, E_1 and E_2 are complex energies of the two objects or particles, and r is the distance between the two objects or particles. This expression (8) may be called a generalized Newtonian gravitational law. Considering the complex energy of a general object or particle that has one real part and two imaginary parts (i.e. $E_1 = E_{1M} + iE_{1Q} + iE_{1C}$ and $E_2 = E_{2M} + iE_{2Q} + iE_{2C}$), we can expand the single complex force into four real and two imaginary forces,

$$\begin{aligned}\vec{F}_{E_1E_2} &= -G\,\frac{M_1M_2}{r^2}\,\hat{r} + \frac{Q_1Q_2}{r^2}\,\hat{r} + \frac{Q_1C_2+Q_2C_1}{r^2}\,\hat{r} + \frac{C_1C_2}{r^2}\,\hat{r}\\ &\quad - i\sqrt{G}\,\frac{M_1Q_2+M_2Q_1}{r^2}\,\hat{r} - i\sqrt{G}\,\frac{M_1C_2+M_2C_1}{r^2}\,\hat{r}\\ &= \vec{F}_{MM} + \vec{F}_{QQ} + \vec{F}_{QC} + \vec{F}_{CC} + i\vec{F}_{MQ} + i\vec{F}_{MC}\\ &= \vec{F}_{RR} + \vec{F}_{II} + i\vec{F}_{RI}\,.\end{aligned} \tag{9}$$

Here, we have used (1)–(3) and (6) for the one real and two imaginary energy expressions. The symbol $\hat{r}$ is the unit vector along the direction of radial distance. We have defined $\vec{F}_{RR} = \vec{F}_{MM}$, $\vec{F}_{II} = \vec{F}_{QQ} + \vec{F}_{QC} + \vec{F}_{CC}$ and $\vec{F}_{RI} = \vec{F}_{MQ} + \vec{F}_{MC}$.

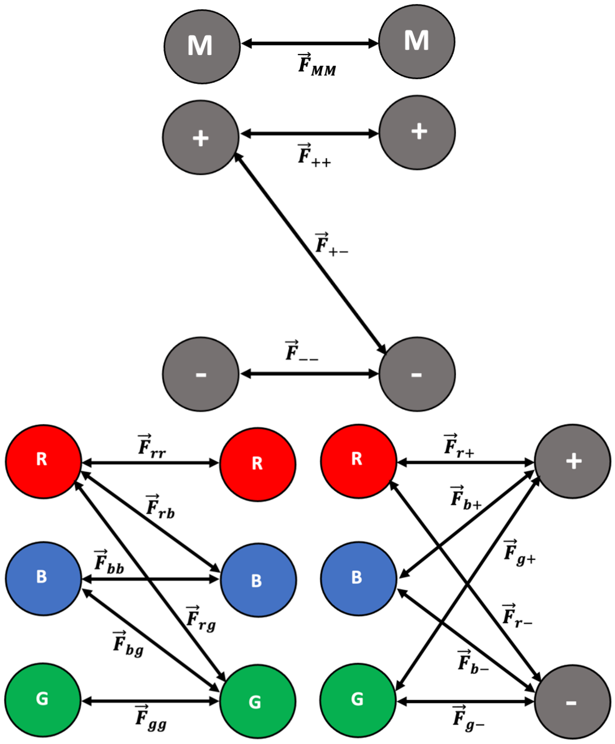

Fig. 4: (a) The top panel shows the gravitational interaction between real energies or masses. (b) The middle panel shows the three types of electromagnetic force between electric charges: the positive-positive, positive-negative, and negative-negative interactions. (c) Bottom left panel shows the six types of strong interactions between color charges: the red-red, red-blue, red-green, blue-blue, blue-green, and green-green interactions. (d) Bottom right panel shows the six types of weak interactions between electric and color charges: the red-positive, red-negative, blue-positive, blue-negative, green-positive, and green-negative interactions.

3.3 Gravitational force — interaction between real energies

The force $\vec{F}_{MM}$ represents Newton's law for the gravitational interaction between two masses. This force governs the orbital motion of astrophysical objects including the solar system. The gravitational interaction is an interaction between real energies (Fig. 4a). Defining the radiation with an equivalent mass, we have a single category for the gravitational force between real energies or masses.

3.4 Electromagnetic force — interaction between electric charges

The force $\vec{F}_{QQ}$ represents Coulomb's law for the electromagnetic interaction between two electric charges. This force governs the orbital motion of atomic electrons around nuclei. Electric charges have two varieties and thus three types of interactions (Fig. 4b, see also Table 3): (1) repelling between positive electric charges $\vec{F}_{++}$, (2) repelling between negative electric charges $\vec{F}_{--}$, and (3) attracting between positive and negative electric charges $\vec{F}_{+-}$. Like charges repel one another and unlike charges attract one another. In the standard model of particle physics, the electromagnetic force between electric charges is described by the group U(1).

Table 3: Gauge field interactions between different types of charges. These include the six strong field interactions between three types of color charges, the six weak field interactions between three types of color charges and two types of electric charges, and the three types of electromagnetic field interactions between two types of electric charges.

Charges/Interactions	r	b	g	$+$	$-$
Red (r)	$\vec{F}_{rr}$	$\vec{F}_{rb}$	$\vec{F}_{rg}$	$\vec{F}_{r+}$	$\vec{F}_{r-}$
Blue (b)		$\vec{F}_{bb}$	$\vec{F}_{bg}$	$\vec{F}_{b+}$	$\vec{F}_{b-}$
Green (g)			$\vec{F}_{gg}$	$\vec{F}_{g+}$	$\vec{F}_{g-}$
Positive ($+$)				$\vec{F}_{++}$	$\vec{F}_{+-}$
Negative ($-$)					$\vec{F}_{--}$

3.5 Strong force — interaction between color charges

The force $\vec{F}_{CC}$ is the strong interaction between color charges. Color charges have three varieties: red, blue, and green and thus have six ($3 + 2 + 1 = 6$) types of interactions (Fig. 4c, see also Table 3): (1) the red-red interaction $\vec{F}_{rr}$, (2) the blue-blue interaction $\vec{F}_{bb}$, (3) the green-green interaction $\vec{F}_{gg}$, (4) the red-blue interaction $\vec{F}_{rb}$, (5) the red-green interaction $\vec{F}_{rg}$, and (6) the blue-green interaction $\vec{F}_{bg}$. Fig. 4c shows these six types of color interactions or strong forces. With anticolors, there are 21 ($= 6 + 5 + 4 + 3 + 2 + 1$) types of strong force between color charges. In the standard model of particle physics, the strong forces between color charges are described by the group SU(3).

In the standard model, the strong interaction can change flavors and colors of quarks in a hadron particle. A typical strong interaction is the proton-neutron scattering, which is an interaction between the color charge of one up quark in proton and the color charge of one down quark in neutron via exchanging a π^+-meson between the proton and neutron. In other words, during this proton-neutron scattering, an up quark in the proton changes into a down quark by emitting a π^+, meanwhile a down quark in the neutron changes into an up quark by absorbing the π^+. A quark with a particular color, when it absorbs a gluon with a different color, changes into a quark with a different color. In the two-flavor multi-excitation model of quarks, quarks do not change flavors and colors but can change states with emissions of quark-antiquark pairs and can be replaced. It should be noted here that the strong force carriers between nucleons are the pion mesons ($\pi^\pm, \pi^0$), which are the lightest hadrons, composed of one first generation or first excited quark and one first generation or first excited antiquark, and bind nucleons to form nuclei. Gluons are the particles that mediate the strong forces that bind quarks together to form hadrons including nucleons. We can categorize the strong force into two categories: (1) the nuclear force between nucleons to bind nucleons to form a nucleus and (2) the color charge interaction or force between quarks to bind quarks into hadrons.

3.6 Weak force — interaction between electric charge and color charge

The force $\vec{F}_{QC}$ is the weak interaction between electric and color charges. Considering electric charges with two varieties and color charges with three varieties, we have also six ($2 \times 3 = 6$) types of weak interactions (Fig. 4d, see also Table 3): (1) the positive-red interaction $\vec{F}_{+r}$, (2) the positive-blue interaction $\vec{F}_{+b}$, (3) the positive-green interaction $\vec{F}_{+g}$, (4) the negative-red interaction $\vec{F}_{-r}$, (5) the negative-blue interaction $\vec{F}_{-b}$, and (6) the negative-green interaction $\vec{F}_{-g}$. With anticolors, there are 12 ($= 2\times 6$) types of weak interactions between electric and color charges. In the standard model of particle physics, the weak forces are described by the group SU(2) and carried by the W and Z bosons. The weak interaction is the only one that can change flavors of quarks in a hadron particle, which causes atoms to change from one element to another. A typical weak interaction occurs when neutron decays into proton with emissions of an electron and an electron-type antineutrino. In this process, a down quark in the neutron changes into an up quark by emitting a W-boson, which lives about 10^{-25} seconds and then breaks into a high-energy electron and an electron-type antineutrino. Like the strong force, we may categorize the weak force into two categories: (1) the weak force between leptons and particles, carried by the W and Z weak bosons, and (2) the weak force between electric and color charges inside a quark.

3.7 Scaling and comparison of fundamental interactions

Considering the strong interaction to be asymptotically free within a typical hadron [22], we can scale the color charge by replacing

$$C \longrightarrow \frac{r}{r_0}\, C\,, \tag{10}$$

where r is the radial distance and $r_0 \sim 10^{-15}$ m is the radius of the typical hadron. This assumption represents that color charge becomes less colorful if it is closer to each other, i.e. asymptotically colorless. Then, the strong interaction between color charges of two quarks can be rewritten by

$$\vec{F}_{C_1C_2} = \frac{C_1C_2}{r_0^2}\,\hat{r}\,, \tag{11}$$

which is independent of the radial distance and consistent with measurements. The weak force between electric charge of one quark and color charge of either another or the same quark becomes

$$\vec{F}_{Q_1C_2} = \frac{Q_1C_2}{r_0 r}\,\hat{r}\,, \tag{12}$$

which is inversely proportional to the distance and consistent with measurements. The electromagnetic force between electric charges of two quarks is given by

$$\vec{F}_{Q_1Q_2} = \frac{Q_1Q_2}{r^2}\,\hat{r}\,. \tag{13}$$

Within a typical hadron (i.e. $r \sim r_0$) such as a proton or a neutron, the strong force can be 100 times stronger than the electromagnetic force in strength. This leads to the color-electric charge ratio of a quark to be $C/Q \sim 10$. The ratio between strong force and weak force will be about $\sim rC/(r_0Q)$. Since the weak force between electric charge and color charge has a shorter range of interaction ($r \sim 10^{-18}$ m or $r/r_0 \sim 10^{-3}$) such as within a typical quark, we have that the weak force between electric and color charge within a typical quark can be 100 times greater than the strong force between color charges of two quarks within a typical hadron. Therefore, the weak force that occurs inside a quark and causes the quark decay is not actually weak, but the strongest.

4 Discussions and conclusions

We have reduced the newly developed four-element theory of nature into a simpler three-element theory of nature by considering radiation and mass are not independent and defining radiation an equivalent mass. The three-element theory suggests that nature consists of only three fundamental elements, which are mass, electric charge, and color charge. Any known matter or particle observed in nature or discovered in labs is a combination of one or more of the three fundamental elements. Fundamental interactions in nature are interactions among these fundamental elements. Mass is a form of real energy. Electric and color charges are two forms of imaginary energy. All fundamental interactions are unified into a single interaction between complex energies. Interaction between real energies is the gravitational field force. Interactions between imaginary energies are the gauge field forces with three categories: (1) the electromagnetic interaction between electric charges, (2) the week interaction between electric and color charges, and (3) the strong interaction between color charges. Interactions between real and imaginary energies are imaginary forces, which do not have observational support but may explain why electric and color charges are usually adhered on masses to form charged particles including quarks, rather than independently exist. The significant results obtained from the new three- or four-element theory of nature such that the weak force is an interaction between electric and color charges would have essential implications to the quark and particle theories beyond the standard as well as the cosmology.

Acknowledgements

The work is supported by the NSF HBCU-UP Research Initiation Award (#2400021). The author also acknowledges the support from the IBM-HBCU Quantum Center.

Received on April 1, 2026

References

1. Zhang T. X. New four-element theory of Nature. *Progress in Physics*, 2025, v. 21, no. 2, 17–146.
2. Zhang T. X. Electric charge as a form of imaginary energy. *Progress in Physics*, 2008, v. 4, no. 2, 79–83.
3. Zhang T. X. Fundamental elements and interactions of nature: A classical unification theory. *Progress in Physics*, 2010, v. 6, no. 2, 36–42.
4. Zhang T. X. Four-element theory of nature and two-flavor multi-excitation model of quarks. American Physical Society (APS) Global Submit Conference, New Perspectives Session, Oral Presentation, Abstract #3, Anaheim, California, March 16–21, 2025.
5. Zhang T. X. Two-flavor multi-excitation model of quarks. *Journal of Modern Physics*, 2025, v. 21, 1437–1446.
6. Zhang T. X. New insights to the weak interaction and quark model. Quark Matter 2023 Conference, Houston, September 3–8, 2023.
7. Azizi K., Agaev S. S., and Sundu H. The scalar hexaquark *uuddss*: a candidate to dark matter? *Journal of Physics G*: *Nuclear and Particle Physics*, 2020, v. 47, 095001.
8. Zhang T. X. Formation of nonaquarks and mysteries of antimatter and dark matter. *Journal of Modern Physics*, submitted.
9. Weyl H. Elektron und Gravitation. I. *Zeitschrift für Physik*, 1929, v. 56, 330–352.
10. Einstein A. Ist die Trägheit eines Körpers von seinem Energieinhalt abhängig? *Annalen der Physik*, 1905, v. 323, 639–641.
11. Einstein A. Übereinendie Erzeugungund Verwandlung des Lichtes betreffenden heuristischen Gesichtspunkt. *Annalen der Physik*, 1905, v. 322, 132–148.
12. Xu S.Y. et al. Discovery of a Weyl fermion semimetal and topological Fermi arcs. *Science*, 2016, v. 349, 613–617.
13. Anderson C. D. The positive electron. *Physics Review*, 1933, v. 43, 491–498.
14. Weinberg S. Charges from extra dimensions. *Physics Letters B*, 1983, v. 125, 265–269.
15. Kaluza T. On the problem of unity in physics. *Sitz. Preuss. Aklad. Wiss. Berlin* (*Math. Phys.*), 1921, 966–972; arXiv: physics.hist-ph/1803.08616.
16. Klein O. Quantum theory and five dimensional theory of relativity. *Zeitschrift für Physik*, 1926, v. 37, 895–906.
17. Klein O. The atomicity of electricity as a quantum theory law. *Nature*, 1926, v. 118, 516–520.
18. Zhang T. X. The 5D fully-covariant theory of gravitation and its astrophysical applications. *Galaxies*, 2015, v. 3, 18–51.
19. Zhang T. X. Electric redshift and quasars. *The Astrophysical Journal Letters*, 2006, v. 636, 61–64.
20. Zhang T. X. Gravitational field shielding and supernova explosions. *The Astrophysical Journal Letters*, 2010, v. 725, L117–L120.
21. Creutz M. Quarks, Gluons, and Lattices. Cambridge University Press, 1983.
22. Gross D. J. and Wilczek F. Asymptotically free gauge theories. I. *Physical Review D*, 1973, v. 8, 3633–3652.