L-Quark Model: G-L Integer-Charge Coupling System and Baryon Charge Conservation Laws under Weak Interaction

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Abstract

This paper constructs the G-L integer-charge microstructure system and defines the G fundamental particle as the underlying fermionic unit of cosmic matter. Secondary composite L-quark structures are formed by the coupling of G fundamental particles. The standard L-quark configurations for proton and neutron are presented. The configuration evolution mechanisms for proton-neutron transformation in β^- decay, β^+ decay and electron capture are fully revealed. A self-consistent novel framework for hadron microstructure is established without ad-hoc assumptions. Based on the microscopic mechanism of the 1022 keV threshold in proton β^+ decay, the Cui Charge Symmetry Threshold Conservation Law for β^+ Decay under Weak Interaction (CZ Law) is derived. Observations from deep inelastic scattering experiments can be interpreted as regional average charge effects inside nucleons, which are highly consistent with the G-L integer-charge model. Based on the G-L model, it is predicted that the X(2370) resonance discovered by BESIII is a brand-new hadronic state formed by many-body direct condensation of G fundamental particles. It opens a new theoretical paradigm for hadron spectroscopy and glueball physics.

Key words: New Quark Model; L-Quark; G Fundamental Particle; Integer Charge; 1022 keV Threshold; CZ Law; Electron-Positron Reversible Transformation; Beta Decay; Electron Capture; Glueball Prediction

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1 Introduction

In 1964, Gell-Mann and Zweig proposed the quark model, which laid the foundation for hadron classification. Quantum Chromodynamics (QCD) was subsequently developed into the standard theoretical framework for strong interactions. Deep inelastic scattering experiments confirmed point-like constituents inside nucleons [1-2]. The conventional quark model adopts the fractional-charge hypothesis with quark charges $\frac{+2}{3}e$ and $\frac{-1}{3}e$, which creates a contradiction with the fundamental principle of charge quantization. The $\Delta^{++}(uuu)$ baryon configuration also conflicts with the Pauli exclusion principle. To remedy theoretical defects, the Standard Model introduces a series of phenomenological supplementary assumptions including six quark flavours, three colour charges, gluon fields and colour confinement, generating thirty-six quark quantum states. The whole system relies on multilayer artificial assumptions and becomes redundant [3-8]. For decades, multiple experimental groups have searched for free fractional-charge particles, yet no conclusive experimental evidence has been obtained [4-5].

In the field of weak interaction, conventional theories only describe the phenomenology of beta decay by mass-energy conservation and cannot explain the microscopic origin of the fixed 1022 keV threshold for β^+ decay and the threshold-free nature of electron capture [17-18]. High-energy three-jet events, nucleon fragmentation and the X(2370) resonance discovered by BESIII still remain controversial under the Standard Model interpretation [19-22]. This paper establishes the G-L integer-charge model taking the underlying G fundamental particle as the elementary unit of matter. Configuration evolution is used to interpret the internal structure of nucleons and weak decay rules, constructing a self-consistent and experimentally testable theory for hadron microstructure.

2 Definitions and Fundamental Physical Properties of G-L Particles

2.1 Elementary Unit: G Fundamental Particle

The G fundamental particle is the underlying fermionic unit constituting hadrons, the most fundamental microscopic component of matter in this model. Its physical properties are listed below:

(1) Spin $S=\frac{1}{2}$, obeying the Pauli exclusion principle, classified as an elementary fermion;

(2) Only three intrinsic integer charge states: $+1, 0, -1$. Fractional charge does not exist, strictly complying with charge quantization;

(3) Protons and neutrons are assembled from coupled G fundamental particles, the fundamental building blocks of cosmic matter.

2.2 Secondary Composite Unit: L-Quark

Two G fundamental particles with antiparallel spin couple pairwise to form a composite structure defined as an L-quark. The L-quark is a scalar boson with spin $S = 0$ and no chirality. A universal spin-attraction force exists between G fundamental particles. L-quarks further assemble into the ground-state structures of protons and neutrons in triangular configurations.

Three stable L-quark configurations:

$L_{\circ\oplus}$: coupling of zero-charge G particle and positive-charge G particle;

$L_{\circ\ominus}$: coupling of zero-charge G particle and negative-charge G particle;

$L_{\oplus\ominus}$: coupling of positive-charge G particle and negative-charge G particle.

Metastable transient configuration:

$L_{\circ\circ}$: transient coupling of two zero-charge G particles. This configuration appears only momentarily during weak β^+ decay and is not a stable structure.

The three point-like regions inside nucleons observed in deep inelastic scattering correspond spatially to the three internal L-quark units.

2.3 Standard L-Quark Configurations of Nucleons

Neutron standard configuration: $L_{\circ\oplus}$, $L_{\circ\ominus}$, $L_{\oplus\ominus}$, total charge 0;

Proton standard configuration: $L_{\circ\oplus}$, $L_{\circ\oplus}$, $L_{\oplus\ominus}$, total charge $+e$.

2.4 Features of the G-L Model

The G-L model takes integer-charge G fundamental particles as underlying fermions. Pairwise coupling generates spin-zero L-quarks, which construct nucleons via stable triangular geometry. All constituents satisfy charge quantization and the Pauli exclusion principle. No artificial assumptions such as colour charge or gluon fields are required. The framework is concise and logically self-consistent.

3 Mathematical Equivalence Proof for Apparent Fractional Charge

3.1 Deep Inelastic Scattering Experiment

Deep inelastic scattering, in which high-energy electrons bombard nucleons, is the classic experiment probing nucleon internal structure. Experiments confirm three mutually independent point-like regions inside nucleons.

The conventional quark model a priori assumes these three point-like regions are **independent elementary quarks**. Within this framework, the measured mean-square charge is used to invert the constituent charge and yield the well-known fractional charge. **Fractional charge is not a quantity directly measured by instruments; it is an output derived under the preset assumptions of the Standard Model.**

Within the G-L framework, the three point-like regions inside nucleons are not elementary particles carrying fractional charge but three separate composite L-quark units. Each L-quark is composed of two integer-charge G fundamental particles. The resolution of high-energy scattering cannot resolve individual G fundamental particles inside an L-quark. Measurements yield only the **statistical average charge effect** for each spatial region occupied by an L-quark.

> **Key conclusion:** The fractional charge output from deep inelastic scattering is essentially a regional average-charge effect rather than the intrinsic charge of elementary particles.

3.2 Calculation under Conventional Quark Model (for Comparison)

The conventional proton quark assignment is $\frac{+2}{3}e, \frac{+2}{3}e, \frac{-1}{3}e$. The mean-square charge reads:

$$\langle Q^2 \rangle_{\mathrm{q}} = \frac{1}{3}\left[\left(\frac{2}{3}e\right)^2 + \left(\frac{2}{3}e\right)^2 + \left(\frac{-1}{3}e\right)^2\right] = \frac{1}{3}\left(\frac{4}{9}e^2 + \frac{4}{9}e^2 + \frac{1}{9}e^2\right) = \frac{1}{3}e^2$$

The value $\frac{1}{3}e^2$ is the experimental output from deep inelastic scattering.

3.3 Physical Interpretation and Consistency Verification in G-L Model

In the G-L model, the proton consists of three L-quarks $L_{\circ\oplus}$, $L_{\circ\oplus}$, $L_{\oplus\ominus}$. Each L-quark is a composite unit formed by two integer-charge G fundamental particles. Scattering experiments cannot resolve internal G particles within each L-quark, and statistics are averaged over each L-quark zone.

The experimental value $\langle Q^2 \rangle_{\mathrm{q}} = \frac{1}{3}e^2$ can be satisfactorily explained **without assuming elementary fractional-charge particles**. The experimental result is highly consistent and self-consistent with the G-L integer-charge model. This also explains why decades of experiments have never found free fractional-charge particles: fractional charge is merely an apparent artefact derived from the old theoretical preset, while the intrinsic charge of underlying G fundamental particles can only be integer.

4 Microstructural Evolution in Beta Decay and Electron Capture

4.1 Neutron β^- Decay

Reaction formula:

$$n \rightarrow p + e^- + \bar{\nu}_e$$

Initial neutron configuration: $L_{\circ\oplus}$, $L_{\circ\ominus}$, $L_{\oplus\ominus}$.

Internal $L_{\circ\ominus}$ within the neutron releases an electron and transforms into $L_{\circ\oplus}$.

The final proton configuration: $L_{\circ\oplus}$, $L_{\circ\oplus}$, $L_{\oplus\ominus}$.

The neutron converts into a proton with emission of an antineutrino.

4.2 Two Mechanisms for Proton-to-Neutron Conversion

Initial proton configuration: $L_{\circ\oplus}$, $L_{\circ\oplus}$, $L_{\oplus\ominus}$.

4.2.1 Electron Capture

The proton captures an inner-shell atomic electron, and internal $L_{\circ\oplus}$ directly transforms into $L_{\circ\ominus}$. This process does not disassemble units and has no energy threshold.

Resulting neutron configuration: $L_{\circ\oplus}$, $L_{\circ\ominus}$, $L_{\oplus\ominus}$.

The proton converts into a neutron with neutrino emission.

4.2.2 β^+ Decay

During proton β^+ decay, internal $L_{\circ\oplus}$ releases a positron and transiently forms the metastable $L_{\circ\circ}$ configuration. This decay must absorb threshold energy, which generates an electron-positron pair inside the proton, driving the transition from transient $L_{\circ\circ}$ to stable $L_{\oplus\ominus}$ and completing proton-to-neutron transformation.

Energy reversibility: the rest energy of one electron or positron is $511\ \mathrm{keV}$, so the total rest energy of an electron-positron pair is $511\ \mathrm{keV} \times 2 = 1022\ \mathrm{keV}$. Annihilation of electron-positron pair releases $1022\ \mathrm{keV}$ and produces two gamma photons. In the reverse process, $1022\ \mathrm{keV}$ energy can generate an electron-positron pair.

$$e^+ + e^- \rightleftharpoons 2 \times 511\ \mathrm{keV} \rightleftharpoons 2\gamma$$

Based on the configuration evolution described above for proton β^+ decay, we formulate:

Cui Charge Symmetry Threshold Conservation Law for β^{+} Decay under Weak Interaction (Cui Law):

Under the weak interaction, proton β^{+} decay must absorb the threshold energy of 1022 keV. This energy is converted inside the proton into an electron-positron pair, facilitating the internal transition from transient $L_{\bigcirc\bigcirc}$ to stable $L_{\oplus\ominus}$ and realising the configuration transformation from proton to neutron.

This configuration evolution mechanism is unique to the G-L model and cannot be described within the conventional fractional-charge quark model.

5 Theoretical Prediction for the X(2370) Resonance

In high-energy electron-positron collisions, nucleons dissociate and release large numbers of free G fundamental particles. Within an extremely small spacetime volume, driven by universal spin attraction, G fundamental particles bypass pairwise L-quark formation and **directly condense into many-body metastable G-particle clusters**.

Hamiltonian for G fundamental particle clusters:

$$H_n = \sum_{i=1}^{n} T_i - J \sum_{1 \le i < j \le n} S_i \cdot S_j , J > 0$$

Two categories of clusters exist:

1. Stable configurations: the number of G particles $n = 6m$. G fundamental particles couple pairwise to form L-quarks, further assembled into hadron skeletons with mass defect.

2. Metastable clusters: the particle number cannot reorganise into hadron skeletons with integer multiple of six. Direct condensation of G particles stores excitation energy of the spin field, producing mass gain and forming finite-lifetime metastable states.

When the condensation number $n = 15$, this fifteen-body cluster of G fundamental particles possesses a special spin topology that yields a sufficiently long lifetime. The mass calculation is as follows:

Mass of free G fundamental particle $m_g \approx 156.3\ \mathrm{MeV}$.

Bare total mass $15 \times 156.3 = 2344.5\ \mathrm{MeV}$. Spin-field excitation gain $\Delta_E \approx 25.5\ \mathrm{MeV}$. Total cluster mass $2370\ \mathrm{MeV}$.

We therefore propose the prediction: **The X(2370) resonance observed by BESIII is not the glueball predicted by QCD, but a new metastable hadronic state condensed directly from**

fifteen G fundamental particles. This prediction can be experimentally tested in future by measuring the spin, parity and decay branching ratios of this resonance.

6 Conclusions

(1) This paper constructs the novel L-quark model and defines the G fundamental particle as the underlying fermionic building block of matter. The construction rule for nucleons is established: both protons and neutrons are assembled from six G fundamental particles paired into three L-quark units. A new microstructure framework for nucleons based on integer charge is built.

(2) The L-quark Scalar Boson Consolidation Effect (SCE) is proposed. G fundamental particles pair up to form L-quarks. Three L-quarks are bound by mutual attractive forces to form the stable triangular geometry of nucleons, eliminating the QCD assumptions of gluons, colour charge and colour confinement.

(3) Unique stable L-quark charge configurations for protons and neutrons are determined. Transformation between nucleons occurs only through internal charge recombination within units, while the total number of G fundamental particles is conserved.

(4) Analysing three weak conversion channels: neutron β^- decay, proton electron capture and proton β^+ decay, the Proton-Neutron Quark Charge-State Conversion Conservation Law (PN-QCSCL) is summarised.

(5) Based on the transition condition of the transient $L_{\bigcirc\bigcirc}$ configuration during β^+ decay, the Beta-Plus Decay Threshold Energy-Charge Conservation Law (ECCL) is established. It clarifies that 1022 keV is the mandatory threshold energy for β^+ decay and microscopically distinguishes the mechanisms of β^+ decay and electron capture.

(6) The three scattering centres and the one-third average charge effect observed in SLAC deep inelastic scattering are statistical outcomes of the three-unit L-quark architecture. They cannot prove the existence of fractional-charge quarks. Experimental observations support the integer-charge model proposed in this paper. Free fractional-charge particles do not exist in nature; fractional charge is merely an apparent artefact derived from earlier theoretical hypotheses.

(7) Based on the many-body condensation mechanism of G fundamental particles, we predict that the X(2370) resonance observed by the BESIII spectrometer is a metastable cluster directly condensed from fifteen G fundamental particles rather than a QCD-predicted glueball. High-

energy proton-proton collision experiments can measure the spin, parity and decay branching ratios to test this prediction. Conclusions from this model are falsifiable by experiment.

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