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The Structure and the Density of a Bare Quark Star in a Cold Genesis Theory of Particles

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Abstract

Based on the preonic structure of quarks obtained in a Cold genesis theory of particles (CGT), it was obtained a semi-empiric relation for the current mass of quarks specific to CGT but with the constants obtained with the aid of the Gell-Mann-Oakes-Renner formula, giving values close to those obtained by the Standard Model, the current quark's volume at ordinary nuclear temperature being obtained as sum of theoretic apparent volumes of preonic kerneloids. The maximal densities of the current quarks: strange (s), charm (c), bottom (b), and top (t) resulted in the range (0.8 - 4.2) × 10^{18} kg/m^3, as values which could be specific to possible quark stars, in concordance with previous results. By the preonic quark model of CGT, the possible structure of a quark star resulted from the intermediary transforming: $N_e(2d+u) \to \overline{s^-} + \lambda^-$ and the forming of composite quarks with the structure: $C^-(\lambda^- - \overline{s^-} - \lambda^-)$ and $C^+(\overline{s^-} - \lambda^- - \overline{s^-})$, and of S_q-layers: $C^+C^-C^+$ and $C^-C^+C^-$ which can form composite quarks: $H_q^{\pm} = (S_q \overline{S}_q S_q)$; $(\overline{S}_q S_q \overline{S}_q)$, corresponding to a constituent mass: $M(H_q) = (12{,}642; 12{,}711)$ MeV/c^2, the forming of heavier quarks inside a quark star resulting as possible in the form: $D_q = n^3 C_q$, ($n \geq 3$). The Tolman-Oppenheimer limit: $M_T = 0.7M_\odot$ for neutron stars can also be explained by the CGT's quark model.

Keywords

Quark Star, Cold Genesis, Current Quark Density, Preons Model, Preon Star, Black Hole

1. Introduction

In the Standard Model (S.M.), it is known the constituent quark model, with a valence current quark (u—up, d—down, s—strange) or (c—charm, b—bottom, t—top) with a current mass [1]: (1.8 - 2.8; 4.3 - 5.5; 92 - 104) MeV/c^2, respective:

(1.27; 4.18 - 4.7; 173) GeV/c^2 and a gluonic shell formed by gluons and sea-quarks [1], the resulting effective quark mass being the constituent quark mass: $m_u = 336$, $m_d = 340$, $m_s = 486$ (MeV/c^2) respective: $m_c = 1.55$, $m_b = 4.73$, $m_t = 177$ (GeV/c^2).

The electric charge of u-, c-, t-quarks is $+(2/3)e$ and the electric charge of d-, s-, b-quarks is $-(1/3)e$, the strong interaction of quarks being explained by so-named "color charge", the gluons having two opposed color charges, the gluon field between a pair of color charges forming a narrow flux tube (as a string) between them (Lund's string model [2]).

In 1975, "jets" of hadrons were seen to emerge from high-energy collisions of electrons and positrons [3]; detailed analysis indicated that these jets were, in fact, the footprints of individual spin-1/2 particles, as expected for quarks.

In 1976, the same physicists that had discovered the ψ-particles at SLAC also identified the τ lepton [4] and in 1977, a fifth kind of quark, dubbed "bottom" or "beauty," was discovered at Fermilab [5]; a sixth quark, called "top" or "truth," is now being sought with a mass at least a hundred times that of the proton.

Visible evidence for gluons was discovered in 1979 at the German laboratory DESY (the Deutsches Electronen-Synchroton), as additional jets of hadrons emerging from electron-positron collisions. Conform to S.M., at high-energies, the "breaking" of gluons into quark-antiquark pairs can occurs, as part of the hadronization process, the upper limit for the gluon's mass experimentally determined being 1 - 1.3 MeV/c^2 [6].

The basic picture of hadrons as composed of quarks and antiquarks bound together by gluons was essentially complete by the end of the 1970s.

Also, the S.M. considers approximately the same size order for the maximum radius of the electron, resulted as scattering center determined inside the electron with X-rays: $\sim 10^{-18}$ m [7] with that of the scattering centers experimentally determined inside the nucleon: 0.43×10^{-18} m [8], considered as quarks in the S.M. and the current quarks are considered un-structured, even if they can transform through weak interactions. As a consequence, the quarks of S.M. cannot explain the mass hierarchy of the elementary particles by the sum rule and without the Higgs mechanism of mass acquiring by coupling to the Higgs field, which also explains the gluons' masses.

In a Cold Genesis pre-quantum theory of particles and fields (C.G.T. [9]-[12]), based on Galilean relativity, it results as a more natural alternative to the possibility of explaining the constituent quarks and the resulting elementary particles as clusters of negatron-positron pairs, named "gammons" ($\gamma(e^-e^+)$), resulting that preonic bosons and quarks can also be formed "at cold", as Bose-Einstein condensate of "gammons" which form quasi-stable basic preons z^0 of mass $\sim 34m_e$, forming constituent quarks (M. Arghirescu, 2006 [9]: p. 58).

This z^0-preon was deduced by calibrating the value: $m_k = m_e/2\alpha = 68.5m_e$ obtained by Olavi Hellman [13], by using the masses of the proton and of the Σ-baryon [9].

The existence of a boson having a mass of $\sim 34m_e$ was evidenced by a research team of the Science' Institute for Nuclear Research in Debrecen (Hungary) [14], which evidenced a neutral super-light particle with a mass of ~17 MeV/c² (~34m_e), named X17, by a reaction:

$$\text{Li7} + \text{p}^+ \to \text{Be*} \to \text{Be8} + \text{b}^0;\ \ \text{b}^0 \to \text{e}^+ + \text{e}^-,\ \ m\left(\text{b}^0\right) \approx 34m_e,$$

that was explained in CGT by the conclusion that z^0-preon is composed by two "quarcins", $c_0^{\pm}$, its stability being explained in CGT by the conclusion that it is formed as a cluster of an even number $n = 7 \times 6 = 42$ quasielectrons, (integer number of degenerate "gammons", $-\gamma^*(e^{*-}e^{*+})$), with mass $m_e^* \approx 34/42 = 0.8095m_e$, *i.e.* reduced to a value corresponding to the charge $e^* = \pm(2/3)e$ by a degeneration of the magnetic moment's quantum vortex $\mathbf{\Gamma_\mu = -\Gamma_A + \Gamma_B}$ generated around super-dense centroids and given by "heavy" etherons of mass $m_s \approx 10^{-60}$ kg and "quantons" of mass $m_h = h\cdot 1/c^2 = 7.37 \times 10^{-51}$ kg.

The considered "gammons" were experimentally observed in the form of quanta of "un-matter" plasma [15].

The m_e^*-value results in CGT by the conclusion that the difference between the masses of neutron and proton: ($m_n - m_p \approx 2.62m_e$) is given by an incorporate electron with degenerate magnetic moment and a linking "gammon" $\sigma_e\left(\gamma^*\right) = 2m_e^* \approx 1.62m_e$, forming a "weson", $w^- = (\sigma_e(\gamma^*) + e^-)$, which explains the neutron in a dynamide model similar to the Lenard-Radulescu model *i.e.*, negatron revolving around a protonic center by the etherono-quantonic pressure of the proton's $\mathbf{\Gamma}_\mu$-vortex with the speed $v_e^* \ll c$, at a distance $r_e^* \approx 1.36$ fm [11]—close to the value of the nucleon's scalar radius: $r_0 \approx 1.25$ fm used by the formula of nuclear radius: $R_n \approx r_0\cdot A^{1/3}$, at which it has a degenerate μ_e^S-magnetic moment and S_e^n-spin, in CGT [9] [10].

The used electron model supposes an exponential variation of its density, given by photons of inertial mass m_f vortically attracted around a dense kernel m_0 and confined in a volume of classic radius $a = 1.41$ fm, (the e-charge in electron's surface), the superposition of the ($N^p + 1$) quantonic vortices, Γ_μ^*, of the protonic quasielectrons, generating a total dynamic pressure: $-P_n(r) = 1/2\rho_n(r)\cdot c^2$, inside a volume with radius: $d^a = 2.1$ fm, which gives an exponential nuclear potential: $V_n(r) = -\upsilon_i P_n$ of eulerian form, conform to:

$$V_n\left(r\right) = \upsilon_i P_n = V_{n0}\cdot \mathrm{e}^{-\frac{r}{\eta^*}};\ \left(V_{n0} = -\upsilon_i P_{n0}\right) \tag{1}$$

with: $\eta^* = 0.8$ fm (equal to the root-mean-square radius of the magnetic moment's density variation inside a neutron, experimentally determined) and υ_i (0.6 fm) the "impenetrable" volume of nuclear interaction [9] [10] [16], the nucleon resulting as formed by $N^p \approx 54 \times 42 = 2268$ quasi-electrons which give a proton's apparent density in its center, (given by the sum rule), of value:

$\rho_n^0 \approx f_c \cdot N^p \cdot \rho_e^0 = 4.54\times 10^{17}$ kg/m³ ($\rho_e^0 = 22.24 \times 10^{13}$ kg/m³), in the CGT's model, the density of the $\mathbf{\Gamma}_\mu$-vortex of a free electron having approximately the same density' variation as the density of photons of its classic volume (of radius a = 1.41 fm), $-f \approx 0.9$ being a coefficient of mass' and $\mathbf{\Gamma}_\mu$-vortex's density reducing in the center of the (quasi)electron at its mass degeneration, its value resulting by the integral of nucleon's mass, considered as given by confined photons, with a density variation: $\rho_n(r) = \rho_n^0(0) \cdot e^{-r/\eta'}$ with η = 0.87 fm (equal to the proton's root-mean-square charge radius, experimentally determined: 0.84 - 0.87).

The value $a_i \approx 0.6$ fm results approximately as the Compton radius of the proton's magnetic moment: $\mu_p = 2.79\mu_N \approx (1/2) e \cdot c \cdot a_i$, ($\mu_N = \mu_{BP}/1836 = 5.05 \times 10^{-27}$ Am^2, the nuclear magneton). Equation (1) gives—with $\upsilon_i(a_i) = 0.9$ fm^3, a value V_n^0 = 115 MeV and: $V_n(d = 2\text{fm}) \approx 9$ MeV—value specific to the mean binding energy per nucleon in the nuclei with the most strongly bound nucleons (9 - 9.15 MeV/nucleon for ^{56}Fe, ^{58}Fe, ^{60}Ni, ^{62}Ni).

The resulting maximal density ρ_n^0 is apparent for the nucleon's center because the centroids of the degenerate electrons of a nucleonic quark are included in the volume of its current mass ("kerneloid"-in CGT [17]), and not in the kerneloid of a single electron, but for Equation (1), it can be used, because at distances over 0.3 - 0.4 fm, the effects of the superposed vortical fields of the nucleon's degenerate electrons are the same, *i.e.*, given by the sum rule, according to the principle of quantum fields' superposition, of Quantum mechanics.

The nuclear force $F_n = -\nabla V_n$ is explained by the conclusion that the dynamic pressure $P_n(r)$ reduces locally also the static pressure $P_s(r)$ of light photons ($m_f \approx$ $(10^{-40}$ - $10^{-41})$ kg), at the surface of nucleon's impenetrable volume $\upsilon_i(a_i)$ of the attracted nucleon oriented toward the attractive nucleon, conform to the Bernoulli's law in the simplest form: $P_s(a_i) + P_d(a_i) = P_s^0(a_i) = \text{constant}$.

Similarly, the strong force between quarks is explained in CGT by a "bag" model [16] resulting from the obtained (multi)vortical model of nucleon by taking $\upsilon_i(r_q) \approx (0.0335 - 0.0388)$ fm^3, ($r_q \approx (0.2 - 0.21)$ fm—the current quark's radius, in CGT, conform to older experiments).

It was also deduced in CGT a quark model of cold forming quark, with effective (constituent) mass giving the particle's mass by the sum rule, by considering as fundamental stable sub-constituent the basic preon $z^0 = 42m_e^* \cong 34m_e$ which can form derived "zerons", (preonic neutral bosons: $2z^0$; $z_1(3z^0)$; $z_2(4z^0)$; $z_\mu(6z^0)$, $z_\pi(7z^0)$,), the light and semi-light quarks ($m_q c^2 < 1$ GeV) resulting by only two preonic bosons: $z_2(4z^0) = 136m_e$ and: $-z_\pi(7z^0) = 238m_e$.

Conform to this model, the mentioned preonic bosons are detectable when they are released in strong interaction or quark's transforming weak interactions as gamma, quantum with specific energy > 1 MeV. For example, the gamma quantum resulted in the transforming reaction: $-\pi^0 \to 2\gamma$ represent a $z_2(136m_e)$—boson, and the gamma quantum emitted in the nuclear reaction: $^7Li + p \to 2\alpha + \gamma$ (17.2 MeV), (used by Cockcroft and Walton in 1932 [18] for verify the formula: $E = mc^2$ and found that the decrease in mass in this disintegration process was consistent with the observed release of energy), represents—according to CGT, a released basic preon z^0 (17.37 MeV).

It is also known that at very large densities, inside neutron stars—having 1 - 3 solar masses, the "Pauli repulsion" [19], *i.e.* the intrinsic repulsion of one nucleon for another (as a consequence of the Pauli exclusion principle), halts the collapse of the star.

However, it was also considered in astrophysics a theoretic (hypothetical) model of an exotic star formed as a network of quarks, named "quark star", formed at extreme temperature and pressure, inside a neutron star [20], when the degeneracy pressure of the neutrons is overcome and the neutrons are forced to fusion, being transformed into their constituent quarks, creating an ultra-dense phase of quark matter based on densely packed quarks, corresponding to a new equilibrium between the pressure force generated by gravitation and the repulsive electromagnetic forces, which impede the total gravitational collapse. The possibility of a self-bound compact star composed entirely of deconfined u-, d-, s-quarks (*i.e.*, bare quark star) has been suggested [21]. Quark stars are considered to be an intermediate category between neutron stars and black holes.

It was theorized that neutron stars having a core consisting of ordinary quark matter (u- and d-quarks) are stable under extreme temperatures and/or pressures, but quark stars consisting entirely of this ordinary quark matter are highly unstable and dissolve spontaneously in another kind of quark matter commonly called "strange quark matter", specific to a "strange" quark star [22], because the interaction of liberated up and down quarks leads to the formation of strange quarks. Observations of supernovae SN 2006gy, SN 2005gj and SN 2005ap suggested the existence of quark stars [23].

It was also concluded [24] that the transition from neutron matter to quark matter begins at densities around (1.5 - 4) × 10^{18} kg/m^3.

However, it was also recognized that the transition point between neutron-degenerate matter and quark matter and the equation of state of quark matter are uncertain [25].

Kojo, Toru ([26], 2016) suggested that typical models predict the phase transition hadron-to-quark as occurring in the interval (2 - 10)ρ_{nuc} with ρ_{nuc} = 2.67 × 10^{14} g·cm^{-3}, (the nuclear saturation density).

It is also known that neutron stars, which are extremely hot when they are formed (~10^{11} - 10^{12} K), cool down thereafter to ~(10^7 - 10^6)K through processes including thermal radiation, neutrino emission and the formation of a solid crust [27].

Logically, the value of transition density from the neutron state of a compressed cold matter to a state specific to a quark star corresponds to a compactness specific to a relation: $\upsilon_Q \approx N_q \upsilon_q$ (as in the case of an atomic nucleus), *i.e.* when the local star's density becomes equal to the density of a current quark heavier than the nucleonic quarks (*i.e.* specific to current quarks of particles heavier than the nucleons).

In this case, for the obtaining of an interval of transition density values specific to the transition from the neutron state to a quark star's state, if we use current quarks masses corresponding to S.M., we must deduce first the specific volumes of the current quarks by the CGT's model of quark, which considers a preonic structure specific to a quasi-crystalline cluster of preonic kernels ("kerneloid"

[17]), considered as the equivalent of the "current mass" concept used by the S.M. for quarks, but in a generalized way (at each level of particle's substructure).

In this paper, after a short presentation of the quarks' preonic structure specific to CGT, necessary for the specific calculation of the current quarks' densities (of their masses and volumes), it is shown that their densities at ordinary temperatures correspond with acceptable approximation to the known limits for the density of a quark star, resulting also a bare quark star's structure specific to CGT and a specific explanation of the initially obtained Tolman-Oppenheimer-Volkoff superior limit for the neutron stars mass ($0.7M_{\odot}$).

2. The Structure of Quarks in CGT

2.1. The Structure of a Nucleonic Quark in CGT

In CGT, similarly to the S.M.'s constituent quark model, it was considered [17] that the electron's mass is formed by a "kerneloid" containing the (super)dense centroid m_0 of radius $r_0 \leq 10^{-18}$ m and by a shell of bosons which are "naked" photons, in concordance with the evidenced possibility to obtain a B-E condensate of photons [28].

This electronic kerneloid is equivalent to an "impenetrable" quantum volume (similar to that of the nucleon), having a radius $r_{ie} \approx 10^{-2}$ fm, in accordance with some high-energy scattering experiments reported by Milonni *et al.* (1994, p. 403 [29]).

The last experimentally determined value for the quark's radius: ~4.3×10^{-19} m [8] corresponds in this case to the radius of the super-dense electronic centroid [12] [17], being close to the upper limit determined by X-rays scattering on electron [7].

The possibility to explain reactions of strong interactions between particles by heavier quarks transforming into lighter quark(s) and bosonic preon(s) specific to CGT but also by heavier quarks forming from these subcomponents indicates that these sub-components maintain their higher stability also in strong interactions, by a quasi-crystalline arrangement of the electronic kerneloids k^e of their z^0-preons, the resulted preonic kerneloids forming the quark's kerneloid—which can be considered as being its current mass.

The radius of the z^0-preon's kerneloid k^z results in CGT of value: $r_z \approx 3.5 \times 10^{-2}$ fm, if it would be spherical (in "melted" drop form), by an empiric equation that for a current u/d-quark considered as spherical uses a radius: $r_q \approx 0.2$ - 0.21 fm, specific to an inflated quark [11] with volume: $\upsilon_{qi} \approx 3.87 \times 10^{-2}$ fm^3 and concordant with older experiments [30] [31]:

$$\vartheta_{ki} = \vartheta_{ni} \cdot \mathrm{e}^{-K\left(1-\frac{m_k}{m_p}\cdot k\right)};\ k = \mathrm{e}^{\left(1-\frac{m_k}{m_p}\right)};\ K = 8.97; \\ \vartheta_{ni}\left(m_p\right) = \vartheta_{ni}\left(0.6\ \mathrm{fm}\right) \approx 0.9\ \mathrm{fm}^3;\ m_p \approx 1836 m_e \tag{2}$$

in which υ_{ni} (0.6 fm) is the volume of the nucleon's "bag" containing rotated and vibrated current u/d-quarks (at ordinary temperature $T_n \approx 1$ MeV/k_B) and thermalized "naked" photons, the term "*k*" taking into account the fact that inside the volume of a bigger particle, υ_{ki} of a smaller particle (current quarks, preonic kerneloids) increases with the local density. Equation (2), for $m_k = m_z^0 = 34m_e$, gives: $\upsilon_{zi} \approx 1.78 \times 10^{-4}$ fm^3, $r_{zi} \approx 3.5 \times 10^{-17}$ m.

For a z^0-preon with $n_z = 42$ quasi-electrons, the electron's kerneloid radius r_{ie} results approximately by: $r_z \approx r_{ie} \cdot n_z^{1/3}$, *i.e.* of value: $r_{ie} = r_{ie}^0 = 0.01\,\text{fm}$, which is the value reported by Milloni [29]. So, in consequence, we will use this value: r_{ie}^0 = 0.01 fm to recalculate the dimensions of the cold z^0-preons and of the cold current u/d-quarks, specific to a quasi-crystalline arrangement of their quasi-electrons (CGT [1] [2]), but as minimal value, of contracted electron's kerneloid, corresponding to a null vibration of the electronic centroids of the preonic cluster of quasielectrons (*i.e.*, to $T_i = 0$ K).

The preonic quasielectrons retain their photonic shell (also at the preon's releasing) by the vortical field of the Γ_μ^e-vortices of the degenerate magnetic moments, maintained by their kernels, in accordance with a classic equation of electron's rest energy [10]:

$$m_e c^2 \approx \frac{1}{2}\int \varepsilon_0 E^2 \mathrm{d}v = \int \mu_0 H^2 \mathrm{d}v; \quad \left(E = cB; r = 0 \div r_\mu = \frac{\hbar}{m_e c} \right) \tag{3}$$

which explains the electron's mass m_e as saturation value: $n \cdot m_f$ of magnetically (vortically) confined "naked" photons (virtually reduced to their inertial rest mass, equivalent to a "'heavy photon" mass in quantum mechanics).

These Γ_μ^e-vortices are maintained by the negentropy of the quantum vacuum given by etherono-quantonic winds (fluxes), which also explains the constancy of the magnetic moment of the free-charged particles in CGT [10].

Equation (3) explains the maintaining of the constituent mass also to quarks changed in strong interaction between interacting particles conform to the sum rule.

The quasi-crystalline arrangement of preonic kerneloids of quarks formed by clusterization is "inherited" from the quarcic non-collapsed quasi-crystalline pre-cluster formed by pre-clusters of $z_2(4z^0)$ and $z_\pi(7z^0)$ preonic bosons (**Figures 1-3**), the quarks confining force resulting in CGT by magneto-electric interaction between quasielectrons and by pressure of kinetized photons giving a repulsive shell of radius 0.6 fm in accordance with a "bag" model of strong interaction with a bag' radius $r_i^* = a_i \approx 0.6\,\text{fm}$ [16], (as in the "bag" model of Toki & Hosaka).

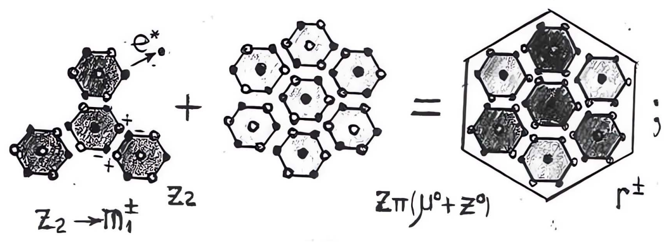


Figure 1. The m_1^*, z_π^* and r^*-quark pre-lusters' forming from z^0-preons [11].

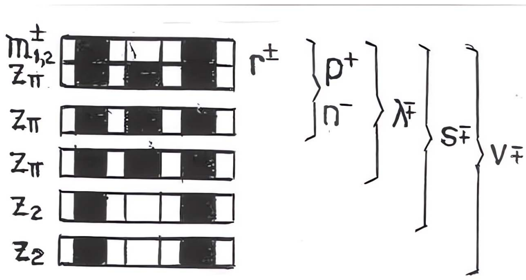


Figure 2. The cold forming of semi-light quarks by pre-clusters of $m_{1,2}$; z_2 and z_π [11].

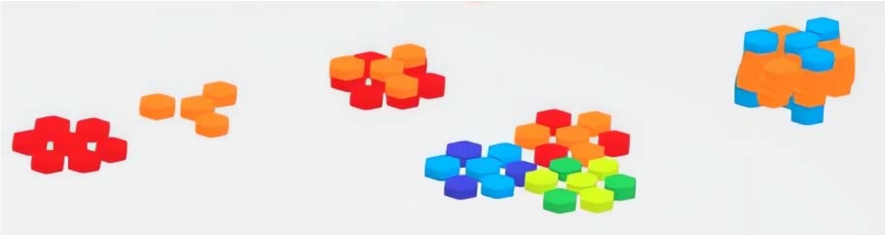


Figure 3. The cold forming of semi-light quarks (3D).

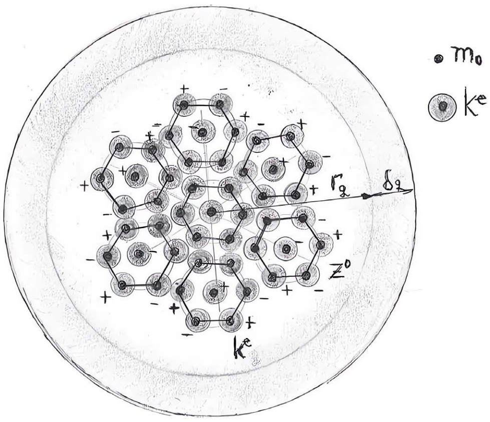


Figure 4. Preonic z_π-layer of quarcic kerneloid [17].

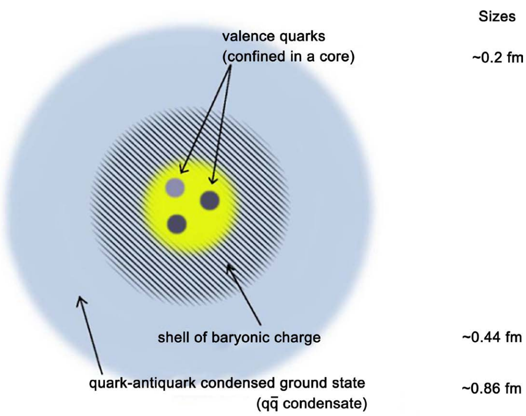
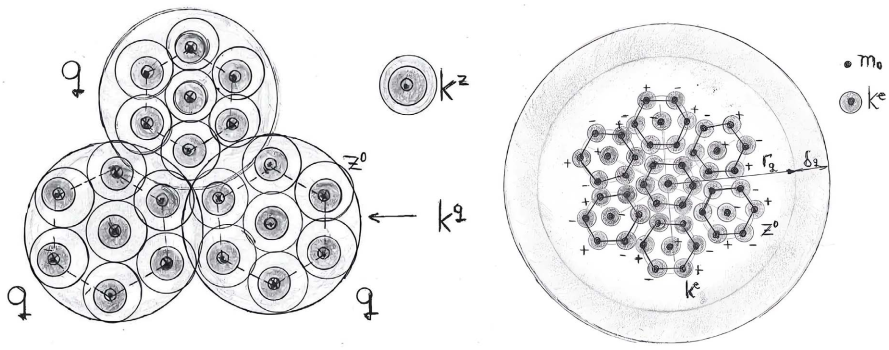


Figure 5. The proton as a Condensate Chiral Bag [30].



(a) (b)

Figure 6. Baryonic and preonic kerneloid.

Figure 4 represents a preonic z_π-layer of a quarcic kerneloid. It results that the radius value: $r_{ie}^0 \approx 10^{-2}$ fm [29] of the quasielectron's kerneloid, ensures a mean distance: $d_i \approx (2/3)\cdot r_z = 2 \times 10^{-2}$ fm between the electronic centroids m_0 on the radial direction at $T = 0$K, which gives a value: $r_{iz} = 3 \times 10^{-2}$ fm for the radius of the kerneloid of the cold z^0-preon, the minimal value of the cold z^0-preon's length resulting of value:

$$l_z^0 = 6 \times d_i \approx 0.12 \text{ fm} .$$

Because the quasi-crystalline structure of (u, d)-quark's kerneloid has three layers in CGT ($m_{1;2}$; z_π; z_π, Figure 2), with (4; 7; 7) z^0-preons, it results at $T = 0$ K a length of the (u; d)-quark' kerneloid: $l_q^0 = 3l_z^0 = 0.36$ fm , and double ($l_q^{0\prime} = 6l_z^0 \approx 0.72$ fm) for the v-quark of CGT.

The minimal radius of the quark's kerneloid (specific to its ultra-cold state, $T = 0$ K) results in value: $r_q^0 \approx 3 \times r_z = 0.09$ fm—which gives a current quark's volume:

$$\upsilon_q^0 = \pi r_q^2 l_q^0 = 0.91 \times 10^{-47} \text{ m}^3 .$$

A cold cluster of three u-d-current quarks will have a radius $r_i^0 \approx 2r_q^0 = 0.18$ fm at $T = 0$ K.

n report to these theoretic values of $T = 0$ K, the value: $r_q^i \approx r_i/2 = (0.2 - 0.21)$ fm used in the CGT's model as the radius of a spherical current u/d-quark in concordance with older experiments [30] [31] represents a radius of the dilated volume of current (u/d)-quark: $\upsilon_q^n \approx (3.35 - 3.38) \times 10^{-47} \text{ m}^3$, that corresponds to a small vibration liberty l_v^z of the z^0-preos inside the quark's kerneloid, which generate a current quark's dilated volume and its repulsive shell, of thickness $\delta_q(l_v^z) \approx (0.01 - 0.03)\text{fm}$ [16], giving a scalar repulsive charge, q_s, and an interaction radius: $r_q^i = r_q + \delta_q$ ($r_q = 0.2$ fm), specific to an ordinary temperature associated to the nucleon's vibration: $T_n^j \approx 1$ MeV/k_B.

The inflated volume υ_q^n of u/d-current quarks can be considered as sum of volumes of dilated kerneloids of vibrated z^0-preons, of radius: $r_k^z = r_z^0 + \delta_z$ (r_z^0—the real radius of z^0-preon's kerneloid), their apparent volume resulting of value: $\upsilon_k^z \approx \upsilon_q^n / 18 = 1.86 \times 10^{-48} \text{ m}^3$, *i.e.* of apparent radius: $r_k^z \approx 3r_k^e \approx 7.6 \times 10^{-2}$ fm , for a volume approximated as spherical (compared to 3.5×10^{-2} fm, for a compact z^0-cluster of quasielectrons at 0 K).

If the dilation of the nucleon's quarcic cluster (at $T \to T_n^j$) is generated more radially than on its length (as a consequence of stronger magnetic interactions between its quasielectrons on length), the ratio: radius/length will tend to: $r_i/h_i \to 2r_q/2r_q = 1$ ($r_q \to 0.2$ fm).

By the value of the nucleon's kernel maximal density obtained in CGT as apparent value, but usable in Equation (1) (4.54×10^{17} kg/m^3), the current quark's radius $r_q \approx 0.2$ fm corresponds to a mass of nucleonic current quark:
$m_n \le m_n^M \approx 8.55$ MeV/c^2, which reduces the mean density of quasi-free photons inside the nucleon's "impenetrable" quantum volume, $\upsilon_i(r_i)$ (r_i = (0.44 - 0.45) fm [30], **Figure 5**).

The mechanic radius r_i^n of the nucleon's impenetrable volume υ_i is given in CGT by a compact cluster of three almost un-vibrated but dilated quarcic kerneloids (**Figure 6**) and it results in value: $r_i^n \approx 2r_q^i = 2\left(r_q + \delta_q\right) \approx 0.44$ - 0.46 fm at $T_n^j \approx 1$ MeV/k_B, in good accordance with the experiments of electrons scattering to nucleons ($r_i \approx 0.44$ fm [30]), while the value $r_i = r_i^f \approx 0.6$ fm represents in CGT the nucleon's kernel radius of interactions by nuclear field and the bag's radius of the "bag" model of strong interaction [16] (used and by the chiral bag model of Toki & Hosaka), obtained as real value by the kinetics of the nucleon's quarcic cluster, *i.e.* by its rotation and by the vibrations of the current u/d-quarks, conform to the CGT's model [16].

Also, for electron, it results in CGT that there are three specific radius, corresponding to three levels of mean density of confined "naked" photons (reduced at their inertial mass: m_f, considered as confined in the photon's kerneloid, of radius $r_f \le 10^{-2}$ fm, for $m_f < m_e$ and having a Γ_μ^f-vortex sustained by a superdense centroid of radius $r_0^f \le r_0 = 0.43 \times 10^{-3}$ fm):

- The super-dense centroid's radius ($r_0 \approx 0.43 \times 10^{-3}$ fm), corresponding to the highest density level ($\rho^0 \approx 10^{20}$ kg/m^3);
- The electron' kerneloid radius ($r_{ie} \ge 10^{-2}$ fm), given by a dense shell of photons, corresponding to the mean density level,
  ($\rho_i^e \le \rho_q^0 = m_q^n / \upsilon_q^0 = 7.5\,\mathrm{MeV/c^2} \times 0.91 \times 10^{-47} = 1.46 \times 10^{18}\,\mathrm{kg/m^3}$) and:
- The electron's classic radius ($a_e \approx 1.41$ fm) corresponds to the low-density level ($\rho_a(a) \approx 5.16 \times 10^{13}$ kg/m^3) and to a quasi-superficial distribution of the electron's e-charge.

2.2. The Structure of Heavy Quarks in CGT

In CGT, the fractional charge of quarks is formal, the particle's charge being given by electron(s) with the degenerate magnetic moment, attached to a neutral cluster of quasi-electrons, and it was found [17] the next structure for the quarks heavier than the nucleonic quarks:

a) $m_s = 0.5$ GeV/c^2 = $978.5 m_e$ ($\approx m_s^* = 987.8 m_e$, ~0.504 GeV/c^2)—the mass of s-quark;

b) m_c = 1.7 GeV/c² = 3326.8m_e—charm quark's mass used by de Souza [32];

c) $m_b \approx$ 5 GeV—bottom quark's mass used by de Souza [32];

d) $m_t \approx$ 175 GeV, the *t*-quark's mass, with current mass resulting as a prismatic cluster:

$$t^{\pm} = (7\times 5)m(b^{\pm}) = \left(17(b\bar{b}) + b^{\pm}\right).$$

The masses m_c and m_b (of quarks charm and bottom) were obtained in CGT by Equation:

$$m_n^{\square}(q_n) \approx m_1 \cdot 3^{n-1};\ q_n = \left[(q\bar{q})q\right]_{n-1} \tag{4}$$

obtained by Karrigan Jr. [33] for quarks of S.M. (for masses: $m_2^{\bullet} = m_c^{\bullet} = 1.55$ GeV/c² and: $m_3^{\bullet} = m_b^{\bullet} = 4.73$ GeV/c², with: $m_1^{\bullet}(q_1) = m_s^{\bullet} \approx 0.486$ GeV/c²), but in the form:

$$m_n(q_n^c) \approx 3^{n-1}\left[m_1 - \frac{z^0}{3}(2n-3)\right],\ (n>1); \tag{5a}$$

or:

$$m_n(q_n^c) \approx 3^{n-1}\left[m_1 - \frac{z^0}{3}\ln\left(3^{n-1}3^{n-2}\right)\right] \tag{5b}$$

by taking: $m_1 = m_v^* \approx 1121.2m_e \approx 0.574\ \text{GeV}$ (the mass of cold v-quark of CGT, instead of $m_s^{\bullet}$), and by considering the resulting quarks c (m_c^+) and b (m_c^-) as de-excited states of the triplet $m_n^{\wedge}$ with mass:

$m_4^* = m(c^*) = 3m_v^*(v^+) = 3363.6m_e$ (1.718 GeV/c²), and respective:

$m_5^* = m(b^{*\pm}) = 3m_c \approx 5.1$ GeV/c² (q*—"cold" quark), by the next de-excitation reactions specific to Equation (5):

$$c^{*\pm}\left[v^{\pm}\cdot\overline{v^{\pm}}\cdot v^{\pm}\right] \to c^{\pm} + z^0(34m_e) \tag{6a}$$

$$b^{*\pm}\left[c^{\pm}\cdot\overline{c^{\pm}}\cdot c^{\pm}\right] \to b^{\pm} + z_3(204m_e);\ \left(z_3 = z_\mu = (2\times 3)z^0 = 2z_1\right) \tag{6b}$$

The quarks of the S.M. result as de-excited quarks of CGT: s^-, c^+, b^-, by the reactions:

$$c(1700) \to c^{\bullet}(1561) + \pi^0(2z_2);\ b(5000) \to b^{\bullet}(4756) + z_6(2z_\pi); \tag{7a}$$

$$s(500) \to s^{\bullet}(483) + z^0 \tag{7b}$$

i.e. by an equation of the form:

$$m_n^c(q_n^{\bullet}) \approx 3^{n-1}\left[(m_1-\delta) + \frac{z^0}{3}(n-2)\right] \approx 3^{n-1}\left[(m_1-\delta) + \frac{z^0}{3}\ln 3^{n-2}\right] \tag{8}$$

$$\left[(m_1-\delta) = \left(2m_s + m_v - z^0\right)/3\right],\ \delta = 55\ \text{MeV/c}^2$$

giving: $n = 2 \to m(q_2^{\bullet})c^2 = 1.557\ \text{GeV} \approx m(c^{\bullet});\ n = 3 \to m(q_3^{\bullet})c^2 = 4.728\ \text{GeV}$.

The Gell-Mann/Okubo mass formula that relates the masses of members of the baryon octet [34]-[36], used by Gell-Mann to predict the mass of the Ω—Baryon in 1962, which is given by:

$$2\left(m_N + m_\Xi\right) \approx 3m_\Lambda + m_\Sigma \tag{9a}$$

is verified in CGT by observing that the known experimental masses give:

$$2\left(m_N + m_\Xi\right) + z^0\left(17\right) = 3m_\Lambda + m_\Sigma$$

and that it results in the next structure specific to CGT:

$$2\left[\left(2n+p\right)+\left(2s+p\right)\right]+z^0 = 3\left(s^\bullet + n + p\right);\ \left(s^\bullet = s - z^0\right) \tag{9b}$$

Equation (9b) is verified by the next weak reactions: 3s → $3s^\bullet + 3z^0$; $s^- + 4z^0 = s + z_2 = v^-$.

3. The Correspondence of CGT's Model with the Quark's Structure of the Standard Model

3.1. The Correspondence with the Values of the Current Quark' Mass Obtained in the S.M.

The resulting structure of quarks in CGT is based on the conclusion that in scattering experiments, the value of the determined radius is inversely proportional to the energy of the scattered particles (X-rays, soft γ-rays or electrons), because the used X-photons or γ-photons have a similar structure to that of the electron and their scattering is the effect of elastic interaction between volumes of the same type, *i.e.* the energy corresponding to a determined scattering radius: $r_0 \le 10^{-18}$ m corresponds to kinetic energy which determines the penetration of the electron's kerneloid by the centroid of the incident particle and the elastic interaction between their centroids.

This conclusion is concordant with the fact that in scattering experiments prior to 1967, at energies up to 20 GeV, researchers observed that the electrons bounced on nucleons like billiard balls, but later, at SLAC (Stanford Linear Accelerator Center), they saw that with more energy they bounced back differently, *i.e.* by a process called ‚deep inelastic scattering', as being scattered on almost point-like "partons" of the proton, thereafter called ‚quarks' corresponding to a three quarks proton model (the cross-sections being estimated by Gottfried).

The previous conclusion can also explain the value of the nucleon' quark's radius:

r_q^n ≈ 0.2 fm, initially deducted for the nucleonic current quark [30] [31], of mass m_u^c.

It is also known that more powerful particle colliders offer a sharper view of the proton; with HERA (Hadron-Electron Ring Accelerator—which operated in Hamburg, Germany), from 1992 to 2007, by electrons having a thousand times more energy than those used by SLAC, physicists could select electrons that had bounced off of extremely low-momentum quarks, and they concluded that these electrons rebounded from a maelstrom of low-momentum quarks and their antiquarks.

As physicists adjusted HERA to look for lower-momentum quarks, these quarks—which come from gluons—showed up in greater numbers. The results suggested that in even higher-energy collisions, the proton would appear as a cloud made up almost entirely of gluons, which abound in a cloud-like form [30] [37].

So, we can conclude by CGT's quark model [11], that the recent value of (u; d)-quarks' radius considered in S.M. (0.43×10^{-18} m) is explained by the higher energy of the incident electrons, whose super-dense centroids penetrated the photonic dense shell of their kerneloids and by the conclusion that the obtained value is the radius of the electron's centroid, the appearance of "gluonic cloud" being given by the rotation of the quark's kernel and of its bosonic shell (of photons in CGT).

Approximating the density variation inside the nucleon's volume as exponential, in the CGT's model [11] [16], for a similar density variation of the constituent quark's volume (excepting the volume of its kerneloid, corresponding to its current mass, $m_q\left(r_q^n\right)$), it results in a transition limit ρ_l corresponding to $r = r_q^n$ (*i.e.*: $\rho_q\left(r_q^n\right) = \rho_l$).

When the mass M_q of a constituent q-quark is increased by a number n of z^0-preons whose kerneloids of mass m_z are included in the sub-structure of its initial current quark, increasing its mass m_q^i with a quantity $\delta m_q = n \cdot m_z$, because the increasing of its total vortical field V_Γ given by its degenerate electrons (Equation (1)) the local density $\rho_q(r)$ is also increased, the inferior limit ρ_l being reached for $r_q' > r_q^n$, corresponding to a higher current mass: $m_q^c > \left(m_q^i + n \cdot m_z\right)$, even if its constituent mass is: $M_q^c = M_q^i + n \cdot M_z$.

If we consider that the current u/d-quarks result by CGT (as cluster of degenerate electrons), with its mean density at most equal to the nucleon's apparent maximal density: $\rho_n^0 \approx 4.54 \times 10^{17}$ kg/m^3 [10] [11], for a nucleonic current quark with radius $r_q^n \approx 0.2$ fm it results in: $m_d^c \le 8.5$ MeV/c^2, this maximal possible value of CGT being close to that obtained by S. Weinberg [38] for the mass of the current d-quark: $m_d \approx 7.5$ MeV/c^2 [38] (instead of ~5.2 - 5.5 MeV/c^2, currently considered by the Standard Model-value calculated by the chiral quark model [39]).

In the mentioned paper, using the known masses of some mesons (π, K) with known structure and the Gell-Mann-Oakes-Renner relation between current quarks masses and the mesons' masses [40], it was calculated that [38]:

$$m(u):m(d):m\left(s^\bullet\right)=1:1.8:36 \tag{10}$$

and by assuming that $m_s^\bullet$ is given approximately by the mass splitting between strange and non-strange particles, it was obtained—for the current quarks masses:

$$m_s^\bullet = 150\ \text{MeV};\quad m_d = 7.5\ \text{MeV};\quad m_u = 4.2\ \text{MeV}.$$

Also, it was calculated that:

$$m\left(b^\bullet\right):m\left(s^\bullet\right):m(d)=590:20:1 \quad \text{and} \quad m\left(c^\bullet\right):m(u)=290:1 \tag{11}$$

!resulting that: $m(c^\bullet) = 1200$ MeV/c^2; $m(b^\bullet) = 4400$ MeV/c^2, and:

$$m(\tau):m(\mu):m(e)\approx 3600:200:1 \tag{12}$$

The constituent quark masses M_q of the naïve quark model include spontaneous effects which give [38]:

$$M_{q^{\bullet}} = m_{q^{\bullet}} + \Delta_{q^{\bullet}}\left(350\ \text{MeV/c}^2\right) \tag{13}$$

the value $\Delta_{q^{\bullet}}$ = 350MeV/c^2 represents the mass of gluonic shell of the current quark and is deduced from the mass of nucleon's constituent u-quark, considering the current mass of u; d-quarks very small compared to their effective mass.

If we choose: $m(u)$: $m(d) \approx$ 2.9 MeV: 5.5 MeV (values currently agreed by S.M. [1]), it results in Equation (10) (*i.e.* with $m(d)$: $m(s^{\bullet})$ = 1.8:36) that: $m(s^{\bullet})$ = 110 MeV, which is close to: $m(s^{\bullet})$ = 104 MeV, currently considered in S.M. The currently accepted values of constituent quarks masses: $M_q = M_s^{\bullet} \approx$ 486 MeV; $M_q = M_c^{\bullet} \approx$ 1550 MeV;

$M_q = M_b^{\bullet} \approx$ 4730 MeV, can be retrieved by a semi-empiric equation obtained by adjusting Equation (13) with: $m_s^{\bullet}$ = 110 MeV:

$$\Delta_{q^{\bullet}} = \left(M_{q^{\bullet}} - m_{q^{\bullet}}\right) = 376\ \text{MeV/c}^2\ ; \tag{14}$$

$$M_{q^n} = m_{q^n} + \Delta_{q^n}\left(350 + 26\right)\text{MeV/c}^2 \tag{15}$$

with: $M_q^1 = M_s^{\bullet}$; $M_q^2 = M_c^{\bullet}$; $M_q^3 = M_b^{\bullet}$, resulting that: $m_c^{\bullet}$ = 1174 MeV/c^2; $m_b^{\bullet}$ = 4354 MeV/c^2 (instead of: 1275 MeV; 4180 - 4420 MeV—currently accepted in S.M. [1]), these values being specific to bound quarks.

We observe that for a better fit with the m_q-values of the S.M., Δ_q should decrease for the charm-quark and increase for the bottom-quark (with ~100 MeV), but such variation is not natural for the composite quark model of CGT, because m_q must have a similar variation as M_q.

We want to see if Equations (13) (15), specific to the S.M., can be adopted for the CGT's model of quark, in which the equivalent of the current quark is the quark's kerneloid and the bosonic equivalent of gluons are the photons of the kerneloid's shell.

For this purpose, we observe that—conform to the S.M.'s quark model, admitting—for a nucleonic quark, the existence of a valence (current) quark with a shell of quarks sea and gluons formed as pairs ($u\overline{u}$), current quarks, the possibility of converting clusters of d-quarks and gluons into s-quarks inside a dense neutron star, at high pressure, with the forming of a "strange" star [22] could result by clusterization of gluons and their adding to the mass of a current d-quark and its transforming into a current s-quark by the u-quark's mass increasing.

This conclusion is in accordance with the chiral quark model, which considers the existence of a quark condensate (also known as a "chiral condensate") as a vacuum expectation value of the composite operators $\left\langle \overline{\psi}_i\left(x\right) + \psi_j\left(x\right)\right\rangle$ generated by a spontaneous symmetry breaking, which implies the conclusion that the quantum vacuum is populated locally by quark-anti-quark pairs (in analogy with the condensation of Cooper electron pairs in a superconductor).

A similar mechanism can also occur in case of the CGT's quark model, which considers a bosonic shell of photons with rest mass (in the Galilean relativity), vortically maintained around the quark's kerneloid, in the base of this similitude and by the fact that these photons having rest mass can be considered pseudo-Goldstone bosons weakly interacting between them but attracted by the quark's current mass (as in case of S.M.'s gluons), we can extrapolate to the CGT's quark model the previous explanation of the quark's current mass increasing to a value higher than that corresponding to the sum rule (Equation(15)).

In this case, if we adopt the obtained new values of m_c and m_b in CGT, it may result that the current quark's bosonic shell has a mass of quasi-constant value: Δ_q = (350 - 376) MeV, for $M_q = M_q$(S.M.), but composed of rest mass photons—in concordance with the possibility to create quarcic pairs (q-$\overline{q}$) from jets of negatrons and positrons (experimentally evidenced).

Equation (15) could be adopted, in this case, also for Souza/CGT variants ('flavors') of quarks, such as the quarks: s(sark): M'_s = 504 MeV/c^2, v(vark): M'_v = 574 MeV/c^2, c(chark): M'_c ≈ 1700 MeV/c^2, b(bark): M'_c ≈ 5000 MeV/c^2 (resulting: m'_s = 128 MeV/c^2, m'_v = 198 MeV/c^2, m'_c = 1324 MeV/c^2, m'_b = 4624 MeV/c^2).

So, conforming to Equations (13) (15), it results that when the number of quasi-electrons which form the preonic quark increases, the supplementary photons vortically attracted by their kernels are included in their current quark's volume, increasing the current quark's density and its mass.

Because in CGT the quarks named in S.M. "charm" and "bottom" are tri-quark clusters, formed by three lighter quarks, it results—in consequence, that only their constituent mass results by the sum rule (by de-excitation reaction), because the current mass of the lighter quarks increases when they form a quarcic cluster which is confined into a bigger current quark, this fact being a consequence of the cluster's confining, which increases the quarcic cluster's density, the inferior limit of quark's local density ρ_l which characterizes the current quark's radius corresponding to a bigger mass after the confining of the composite quark's cluster.

Also, if we identify in CGT the current quark's volume with the volume of its kerneloid, it results in this case that the density of the bound basic z^0-preon is increased proportionally with the mass of the current quark in which it is included, by the fact that in CGT the spontaneous symmetry breaking and the mass acquiring mechanism suppose the forming of etherono-quantonic vortices around the super-dense kernel of degenerate electrons and the confining of a specific mass of photons (especially photons with bigger mass/volume of their kerneloids) around their superdense kernel.

In this case, the phenomenon of preons' current mass increasing with the particle's mass can be explained in CGT by the fact that the force $F_v = -\nabla V_\Gamma$ given by the total vortical field of the N^e quasielectrons forming z^0-preons (included into the quark's kernel) retains the inertial masses of internal photons inside the quark's kerneloid by a force of static quantum pressure gradient generated conform to the Bernoulli's law, by a dynamic quantum pressure (Equation (1), which increases proportional to the number of z^0-preons, *i.e.* proportional to the quark's mass:

$$F_v(r) = -\nabla V_{\Gamma}(r) = -N^e \cdot \nabla V_{\Gamma}^e(r); \left(V_{\Gamma}^e(r) = -\frac{1}{2}\upsilon_f \rho_s c^2\right) \quad (16)$$

(υ_f—the volume of the photon's kerneloid, containing its inertial mass; $1/2(\rho_s c^2)_r$—the dynamic etherono-quantonic pressure in the Γ^e—vortex of a bound quasielectron at r-distance).

Equation (16) (specific to CGT) can explain Equation (15) (specific to S.M.) by the conclusion that even if the mass per bound quasielectron (given by its kerneloid and its photonic shell—in CGT [11] [17]) remains quasi-constant (according to the sum rule—applied by CGT), a part of the photons corresponding to the current quark's photonic shell, of mass proportional to the quark's mass (to N^e), is included into their kerneloid (into their current mass) as a consequence of the $F_v(r)$—force' increasing with the constituent quark's mass.

Because in CGT, it results for u/d-quarks that: $M_u \approx 312$ MeV/c²; $M_d \approx 313.5$ MeV/c² [9]-[11] (values which give the nucleon's mass by the sum rule) and $m_d \le 8.5$ MeV, then the current quark's mass: $m_d = (5.5; 7.5)$ MeV/c² and $m_{s^\bullet} = (486)$ MeV/c² correspond to the differences: $\Delta_d = M_d - m_d = (306 - 308)$ MeV/c², respective: $\Delta_{s^\bullet} = (350 - 376)$ MeV/c²—obtained by Equations (13) (15), which indicates an increasing of Δ_q with m_q ($\Delta_s \ne \Delta_d$), contrary to the S.M.'s Equation (13).

A semi-empiric relation which can include the mentioned values of m_d in correlation with the value of M_d specific to CGT (inspired by the proportionality: $M_p^2 \sim (m_{q1} + m_{q2})$, specific to the Gell-Mann-Oakes-Renner relation [40]), can result as ansatz, in the form:

$$m_q = M_q - \Delta_q = M_q - A_q \cdot \mathrm{e}^{k_q \cdot \left(1 - \frac{M_{S^\bullet}^2}{M_q^2}\right)} \ \mathrm{MeV/c^2}; \quad (17)$$

with $M_{s^\bullet} = M_s^\bullet$ (486 MeV)—the constituent mass of s•-quark. The constants A_q, k_q, must be obtained by taking: $m_d = 7.5$ MeV/c² [38] or $m_d^\bullet \approx 5.2 - 5.5$ MeV/c² (S.M.).

For $m_d = 7.5$ MeV/c² and the ratio: $m_s/m_d \approx 20$ (Equation (10)) → $m_s^\bullet \approx 150$ MeV/c² [38]), with: $\Delta_d = (M_d - m_d)_{\mathrm{CGT}} = (313 - 7.5) = 305.5$ MeV/c² and by the values of M_q which result in CGT as specific to de-excited quarks [17] (specific also to S.M.'s mass variant), *i.e.*:

$M_q = \left(M_d; M_s^\bullet; M_c^\bullet; M_b^\bullet\right)_{\mathrm{CGT/SM}} = (313; 486; 1557; 4730)\ \mathrm{MeV/c^2}$, it results:

$A_q = 336$ MeV/c², $k_q \approx 0.0674$, and:

$\Delta_d = 305.5$ MeV/c²; $\Delta_{s^\bullet} = 336$ MeV/c²; $\Delta_{c^\bullet} = 357$ MeV/c²; $\Delta_{b^\bullet} = 359.2$ MeV/c², and: $m_d = 7.5$ MeV/c²; $m_s^\bullet = 150$ MeV/c²; $m_c^\bullet = 1193$ MeV/c²; $m_b^\bullet = 4370$ MeV/c², these values being relative close to those given by Equation (11), obtained in [38] by $m_d = 7.5$ MeV/c²: (150; 1200; 4400) MeV/c² and less to those currently used in the S.M.

We observe—in consequence, that Equation (17), which considers a low increasing of Δ_q with M_q, gives m_q-values close to those obtained in the S.M. by m_d = 7.5 MeV/c^2, being in same-time more natural than Equation (13) of the S.M. (at least for the CGT's quark model).

For $m_d^\bullet \approx 5.5$ MeV/c^2, by $m_s^\bullet \approx 110$ MeV/c^2 given by Equation (10), and with: $\Delta_d = (M_d - m_d)_{CGT} = (313 - 5.5) = 307.5$ MeV/c^2, using the values of M_q which result in CGT as specific to de-excited quarks ($M_{q\bullet}$), by Equation (17) it results:
$A_q = 376$ MeV/c^2, $k_q \approx 0.14246$, and:
$\Delta_{d\bullet} = 307.5$ MeV/c^2; $\Delta_{s\bullet} = 376$ MeV/c^2; $\Delta_{c\bullet} = 427.5$ MeV/c^2; $\Delta_{b\bullet} = 433$ MeV/c^2,
$m_d^\bullet = 5.5$ MeV/c^2; $m_s^\bullet = 110$ MeV/c^2; $m_c^\bullet = 1122.5$ MeV/c^2; $m_b^\bullet = 4297$ MeV/c^2, these values being relatively close to those specific to the S.M. (5.2; 104; 1275; 4210)$^\bullet$ MeV/c^2 (with a higher difference at $m_c^\bullet$, as in case of the using of Equation (15)).

3.2. The Compatibility with CGT of the Values (5.5; 7.5) MeV/c² of the D Quark's Current Mass

The value m_d = 7.5 MeV/c^2 of the current d-quark [38] (which in CGT is a little higher but almost equal to the u-quark's current mass), is correspondent to the CGT's model of nucleon, in the next way:

If the proton results as a cluster of N^p-degenerate electrons whose degenerate mass $m_e^* \approx 0.81 m_e$ is given almost integrally by photons with rest mass vortically maintained inside a volume of classic radius: a = 1.41 fm having a mass density with exponential variation: $\rho_e(r) = \rho_e^0 \times e^{-r/\eta^*}$ (ρ_e^0 = 2.224 × 10^{14} kg/m^3), then we can approximate the proton's density variation by the sum rule, as:
$\rho_n(r) = \rho_n^0(0) \cdot e^{-r/\eta^*}$ with: $\rho_n^0 \approx f \cdot N^p \rho_e^0$ ($f \approx 0.9$) and η^* = 0.87 fm (proton's root-mean-square charge radius, experimentally determined: (0.84 - 0.87) fm [41]), the proton's mass ($m_p \approx 1.67 \times 10^{-27}$ kg) resulting by choosing a proton's scalar radius: $r_s^p \approx a$ = 1.41 fm (instead of 1.25 fm—specific to the formula of nucleus' volume, determined in concordance with experimental observations [31]), because the CGT's expression: $e = 4\pi a^2/k_1$ (which explains the Lorentz force as being of Magnus type by: $k_1 = 1.56 \times 10^{-10}$ [m^2/C]), conform to the next relation:

$$M_p = 4\pi \cdot f N^p \rho_e^0 \int_0^a r^2 e^{-\frac{r}{\eta^*}} = 4\pi \rho_n^0 \cdot (\eta^*)^3 \left\{ 2 - \left[\left(\frac{r}{\eta^*} \right)^2 + 2\frac{r}{\eta^*} + 2 \right] e^{-\frac{r}{\eta^*}} \right\} \quad (18)$$

($r = a$ = 1.41 fm), the value of the maximal density: ρ_n^0 = 4.54 × 10^{17} kg/m^3 is an apparent value for nucleons because the fact that a part of the mass $m_i(r_i)$ of the "impenetrable" quantum volume $\upsilon_i(r_i)$, given by photons with rest mass, is confined around the electronic centroids forming three kerneloidic clusters of dilated volume, of radius $r_q \approx 0.2$ fm and mass corresponding to a current quark's mass ($m_q \approx 5.5$ - 7.5 MeV/c^2, by concordance with the S.M. by Ref. [38]), which by photons confining reduces the total mass: $\Delta m_i = (m_i - 3m_q)$ of (quasi)free photons inside the υ_i-volume.

Approximating that this total mass Δm_i of photons, remained inside υ_i-volume, is of quasi-constant density $\rho^* = \rho_i(r^*)$, we must have also:

$$\Delta\upsilon_i = \left(\upsilon_i\left(r_i\right) - 3\upsilon_q\right) \Rightarrow \Delta m_i \approx \rho^* \cdot \Delta\upsilon_i = \left(m_i\left(r_i\right) - 3m_q\right); \quad (19)$$

$$\left(\rho^* = \rho_i\left(r^*\right) \approx \rho_n\left(r^*\right); \upsilon_q = \upsilon_q\left(r_q\right)\right)$$

It can be verified, by calculating the m_i—mass with Equation (18), that the equality (19) is satisfied, for $m_d \approx 7.5$ - 7.8 MeV/c^2, by $\rho^* = \rho_i(r^*)$, at $r_i = r^* \approx 0.43$ - 0.45 fm—values which represent almost the inferior limit of the nucleon's impenetrable volume radius experimentally determined (0.44 fm [30]), corresponding to a quarks' arrangement conform to **Figure 6**. This r_i-value gives for υ_i a mean density: $\rho_i(r_i) \approx (2.7$ - $2.77) \times 10^{17}$ kg/m^3, while the density of a nucleon's current quark of mass $m_d = 7.5$ MeV/c^2 and $r_q \approx 0.2$ fm, has a density: $\rho_d \approx 4 \times 10^{17}$ kg/m^3, so of ~1.48 times higher than $\rho_i(r_i)$, in accordance with the conclusion that these u/d-current quarks are generated by a breaking symmetry, as confined (photonic) matter of nucleon's υ_i-volume, by the total vortical field of their quasielectrons, conform to CGT (Equation (16)), while the density of a d-quark with $m_q = 5.5$ MeV/c^2 ($\rho(5.5) \approx 2.93 \times 10^{17}$ kg/m$^3 = \rho_s$), would be at $r_i = r^* = 0.45$ fm, of only 1.08 times higher, and it can be considered a saturation value ρ_s for the density of quasi-free photons inside $\upsilon_i(r^*)$; it also corresponds approximately to the charged pion condensation, which occurs at low temperatures and densities of order 3×10^{17} kg·m^{-3} (S. N. Shore [24]), this value being a little higher than the nuclear saturation density: $\rho_n^s \simeq 2.67 \times 10^{14}$g·cm^{-3}.

Using in Equation (19) the value: $r^\bullet = 0.44$ fm—experimentally determined [30], with Equation (18) it results: $m_d = 7.64$ MeV/c^2 and the value $r^\bullet = 0.45$ fm gives $m_d = 7.8$ MeV/c^2.

Calculating $m_i(r^\bullet = 0.44$ fm) with Equation (18), it results in the next values:

$m_i(r^\bullet) = 0.111194 \times 10^{-27}$ kg; $\Delta\upsilon_i = (\upsilon_i(r^\bullet) - 3\upsilon_q) = 0.25664 \times 10^{-45}$ fm^3; $\rho_n(r^\bullet) \approx 2.74 \times 10^{17}$ kg/m^3; and with $\rho^* \approx \rho_n(r^\bullet)$, it results: $-\Delta m_i = \rho^*\Delta\upsilon_i \approx 0.0703 \times 10^{-27}$ kg, which gives:

$m_q \approx (m_i(r^\bullet) - \Delta m_i)/3 = 0.0136$ kg ≈ 7.64 MeV/c^2, the value $m_d = 7.5$ MeV/c^2 corresponding to a mean density $\rho^* = \rho_m$, given by an exponential variation, for example, of the form:

$\rho_i\left(r\right) = \rho_i^0 \times \mathrm{e}^{-r/\eta_i}$ ($\rho_i^0 = \rho_s = 2.93\times10^{17}\ \mathrm{kg/m^3}$); $\rho_m = \rho_s\left(\eta_i/r^*\right)\int \mathrm{e}^{-r/\eta_i}\mathrm{d}r$ ($0 \le r \le r^*$), which, by $\rho_i(r^*) = \rho_n(r^\bullet)$, gives: $\eta_i = 5.5$ fm; $\rho_m \approx 2.8 \times 10^{17}$ kg/m^3 and $m_q \approx 7.4$ MeV/c^2.

The value $r_i = r^* \approx 0.43$ - 0.45 fm corresponds to a vibration liberty δ_v^c of small amplitude of the current quarks inside the nucleon's impenetrable volume, and in this case, the value: m_d^* = (7.5 - 7.8) MeV (with the current mass m_u of u-quark with at most 1 MeV/c^2 lowed than m_d, in CGT, and M_u with $2.62m_e$ lower than M_d) corresponds to almost maximal compactness at nuclear temperature $T_i = T_n^j \approx 1$ MeV/k_B, specific to a mechanical interaction between two nucleons (the value $r_i \approx 0.59$ - 0.6 fm corresponding to a real amplitude $\delta_v^r > \delta_v^c$ of current quarks' vibration inside the nucleon's impenetrable volume), the quark's radius $r_q = 0.2$ fm corresponding to a dilated quark, with intrinsic vibrations.

Conform to Equation (19), the variation of the density of confined (quasi)free photons inside the proton's volume containing three quarks of current mass $m_q = m_d^*$ can be roughly approximated for the CGT's nucleon model, by:

$$\rho_n(r) = \begin{cases} \rho_n^0 \cdot e^{-\frac{r^*}{\eta^*}}, & r = (0 \div r^*) \\ \rho_n^0 \cdot e^{-\frac{r}{\eta^*}}, & r = (r^* \div a) \end{cases}, \quad (r^* \approx 0.44\ \text{fm};\ a = 1.41\ \text{fm}) \tag{20}$$

This variation is specific to the quarks' existence inside the impenetrable nucleon's volume, but it doesn't change the expression of the nuclear potential (Equation (1)), because the vortical field generated by two z^0-preons-diametrically opposed in the report to the nucleon's center acts as a vortical field generated by identical z^0-preons positioned in the proton's center.

It must be mentioned that Equations (18) (20), using a proton's scalar radius: a = 1.41 fm (conform to Equation: $e = 4\pi a^2/k_1$), corresponds to a gauge model of nucleon (in classical sense), in the context in which it is recognized that although the charge and spin of the proton have been extensively studied for decades, relatively little is known about its mass distribution, because a part of nucleon's mass is given by its bosonic shell (gluonic, in the S.M.), the proton's scalar radius being the largest [42].

For $r^* \approx 0.39$ fm, corresponding to $\rho_n(r^*) = 2.9 \times 10^{17}$ kg/m^3 $\approx \rho_s$, the relation (19) is satisfied approximately for a d-quark's current mass: $m_d \approx 6.5$ MeV/c^2, but the value $r^* \approx 0.39$ fm corresponds in CGT to a quarks' arrangement as in **Figure 6** (minimal radius of the quarks' cluster: $r^* = 2r_q \approx 0.4$ fm), *i.e.*, to a compact cluster of quarks, as in case of a cold nucleon.

Because in CGT, it results that ρ_n (r^* = 0.39 fm) is very close to: ρ'_q (5.5 MeV) = 2.93 kg/m^3, it results from the previous observations that a cluster of three current quarks q(~5.5 MeV), even if it can exist inside the nucleon's impenetrable quantum volume almost as a single particle, it must have a higher mass.

So, the value m_d = 7.5 MeV results as more plausible than the value: m_d = (5.5 - 6) MeV, in CGT.

3.3. The Calculation of the Current Quarks' Masses in CGT

Another argument which indicates that the value m_d = (7.4 - 7.5) MeV is more plausible than the value $m_{d'}$ = (5.2 - 5.5) MeV for a nucleonic d-quark is the next reason:

The ratio: $m_s/m_d \approx 20$, which by m_s = 104 MeV/c^2 gives in the S.M., the value: 5.2 MeV/c^2, was obtained by the Gell-Mann-Oakes-Renner (GMOR) relation [40] between light current quarks masses m_q and the mesons' masses, M_π, M_K:

$$M_\pi^2 = -\left(\frac{2}{f_\pi}\right)^2 \left\langle \bar{d} \cdot d \right\rangle_0 (m_u + m_d) \approx B(m_u + m_d);\ B = -\left(\frac{2}{f_\pi}\right)\left\langle \bar{\psi} \cdot \psi \right\rangle \tag{21}$$

with f_π—the pion decay constant (190 MeV in Ref. [33] and 130 MeV-currently considered), which indicates the strength of the chiral symmetry breaking, with

$\langle \bar{\psi} \cdot \psi \rangle$ the chiral condensate and by the approximation: $\langle \bar{u} \cdot u \rangle_0 = \langle \bar{d} \cdot d \rangle_0 = \langle \bar{s} \cdot s \rangle_0 = \langle \bar{q} \cdot q \rangle_0$ (for perfect SU(3) flavor symmetry of the QCD vacuum condensate), but considering the mesons' forming by nucleonic quarks, giving an oversized current mass of their kernels, this structure of the π-mesons supposing that the same valence quark maintains attracted around it a mass of gluonic shell of almost five times higher when it is included in a baryon than that maintained inside a π-meson, *i.e.*, contrary to Equation (14).

In CGT, this un-natural supposition is avoided by the fact that the structure of π-mesons and partially—and the structure of K-mesons include mesonic quarks ("mark"—$m_{1,2}$), of mass M_m = 69.5 MeV/c², *i.e.* of 4.5 times lighter than the nucleonic (u/d)-quarks.

Because inside the π-meson the density of the m-quark's kernel cannot be higher than inside a nucleon, conform to Equation (16), the current mass of the m-quarks specific to CGT results of value: $m_m \approx m_d/4.5$, *i.e.*, $m_m^{\bullet} \approx 1.(2)$ MeV/c² if $m_d = m_d^{\bullet} = 5.5$ MeV/c² (•—corresponding to the S.M.) and $m_m \approx 1.(6)$ MeV/c² if $m_d = 7.5$ MeV/c² (conform to CGT's conclusion).

Also, the ratio: $m_d/m_u = 1.8$ (Equation (10)) is specific to a mass difference: δm = 5.2 − 2.9 = 2.3 MeV/c² = $4.5m_e$—which is higher than the mass difference between the masses of the neutron and the proton (~$2.6m_e$), which in CGT is specific to the difference between M_d and M_u.

The ratio: $m_d^-/m_u^+ = 1.8$ maintained in S.M., obtained in Ref. [33], is specific in CGT, at least formally, to the ratio m_m^-/m_m^+, because it was obtained by GMOR relation, which in CGT gives:

$$\frac{m_m^-}{m_m^+} = \frac{M^2(K^0) - M^2(K^+) + M^2(\pi^+)}{2M^2(\pi^0) + M^2(K^+) - M^2(K^0) - M^2(\pi^+)} = 1.84; \quad (22a)$$
$$\left(K^0 = \bar{\lambda} + m_2^-; \pi^0 = \bar{m}_{1,2} + m_{1,2}\right)$$

So, considering (for conformity with the S.M.) that $m_m^-/m_m^+ \approx 1.8$, it results in: $m_m^+ \approx$ (1.(2)•; 1.(6)) MeV/c² we have: $m_m^- \approx$ (1.(2)•; 1.(6)) × 1.8 = (2.2•; 3) MeV/c².

Taking into account the fact that the mass M_K of the K-mesons results in CGT [10] [17] by a m-quark and a λ-quark (M_m = 69.5 MeV/c²; M_λ = 435.3 MeV/c²), by Equation (21) it results with the theoretic M_p—masses obtained in CGT [10] [17], that:

$$\left(M_{K^0}/M_\pi\right)_t^2 = (989.6/275.6)^2 = \frac{m_{m^-} + m_\lambda}{2m_{m^-}} = 12.9; \Rightarrow \frac{m_\lambda}{m_{m^-}} = 24.8 \quad (22b)$$

while with the experimentally obtained values it results: $\left(M_{K^0}/M_\pi\right)_e^2 = 13.5$; $m_\lambda/m_{m^-} = 26$.

So, with $m_m^{\pm} \approx$ (2.2•; 3) MeV/c² we would have: m_λ = $(54.5_t; 57.2_e)^\bullet$; $(74.4_t; 78_e)$ MeV/c².

However, for $M_s(s^\bullet)$ = 486 MeV/c², we can also use the CGT's model [17], resulting that:

$$\left(M_{\eta^\bullet}/M_\pi\right)_t^2 = (1091.6/275.6)^2 = \frac{m_{m^-} + m_s^\bullet}{2m_{m^-}} = 15.688;\ \Rightarrow \frac{m_s^\bullet}{m_{m^-}} = 30.37 \quad \text{(23a)}$$

(M_p, given by CGT, in m_e), so with m_{m^-} ≈ (2.2•; 3) MeV/c² we have: $m_s^\bullet$ = (66.8•; 91.1)$_t$ MeV/c².

With the experimentally obtained value of M_{η^0} (1073 MeV/c²), it results: $\left(M_{\eta^0}/M_\pi\right)_e^2$ = 16.5; $m_s^\bullet/m_{m^-}$ = 32, values which by m_{m^-} ≈ (2.2•; 3) MeV/c², give: $m_s^\bullet$ = (70.4•; 96) MeV/c².

We observe that by CGT and Equation (21), the obtained value of $m_s^\bullet$, which is correspondent with the inferior limit agreed by the S.M. (92 MeV/c²), is the value:

$m_s^\bullet$ = 91.1 MeV/c², obtained by: m_d = 7.5 MeV/c², that gives: m_m^+ ≈ 1.(6) MeV/c² (corresponding to M_{m+} ≈ 69.1 MeV/c²) and: m_{m^-} ≈ 3 MeV/c², corresponding to

M_m ≈ 70.4 MeV/c² and to: $\Delta_{s\bullet} = M_s^\bullet - m_s^\bullet$ = 395 MeV/c².

Also, for $M_s(s)$ = 504 MeV/c² [10] (non-de-excited s-quark of CGT [17]), it results in that:

$$\left(M_{\eta^0}/M_\pi\right)_t^2 = (1125.6/275.6)^2 = \frac{m_{m^-} + m_s}{2m_{m^-}} = 16.68;\ \Rightarrow \frac{m_s}{m_{m^-}} = 32.36 \quad \text{(23b)}$$

(M_p in m_e), so with m_{m^-} ≈ 3 MeV/c² we have: m_s = 97.1 MeV/c² and $\Delta_s = M_s - m_s$ = 407 MeV/c².

We can verify if the theoretically obtained ratios: m_λ/m_{m^-} = 24.8 and: $m_s^\bullet/m_{m^-}$ = 30.37 are concordant with the experimentally obtained masses of mesons η^0 $(1073m_e)_e$ and K^0 $(974.5m_e)_e$ by the GMOR relation and the Gell-Mann-Okubo relation, written in the form :

$$\frac{3\cdot M^2\left(\eta^0\right)_e}{4M^2\left(K^0\right)_e - M^2\left(\pi^0\right)_e} = 0.927 \approx \frac{3\left(m_{S\bullet} + m_m^-\right)}{4\left(m_\lambda + m_m^-\right) - 2m_m^-} = \frac{3\left(m_{S\bullet}/m_m^-\right) + 3}{4\left(m_\lambda/m_m^-\right) + 2} = 0.93; \quad \text{(23c)}$$

By Equation (17), recalculating the values A_q and k_q by the conditions: $\Delta_{s\bullet}$ = 395 MeV/c² and: Δ_d = (313 − 7.5) = 305.5 MeV/c², we obtain:

$A_q = \Delta_{s\bullet}$ = 395 MeV/c²; k_q = 0.182, which give:

Δ_s = 400 MeV/c²; m'_s = 104 MeV/c², that compared to: m_s = 97.1 MeV/c² (by Equation (23b)), gives a difference of 7% which indicates that Equation (17) and the obtained values for A_q, k_q, are satisfactory.

For the quarks c• and b•, and: c and b, by Equation (17), for m_d = 7.5 MeV/c² we obtain:

$\Delta_{c\bullet}$ = 465.4 MeV/c², $m'_{c\bullet}$ = 1091 MeV/c², and: $\Delta_{b\bullet}$ = 473 MeV/c², $m'_{b\bullet}$ = 4257 MeV/c².

For the Souza/CGT variants (flavors) of quarks, *i.e.* with $M_q = M'_q$:

(M'_s = 504; M'_v = 574; M'_c ≈ 1700; M'_b ≈ 5000) MeV/c², Equation (17) gives:

(Δ'_s = 400; Δ'_v = 416; Δ'_c = 466.8; Δ'_b = 473) MeV/c^2, and:

m'_s = 104 MeV/c^2; m'_v = 158 MeV/c^2; m'_c = 1233 MeV/c^2; m'_b = 4527 MeV/c^2.

So it results in CGT, by the aid of Equation (17), values of $m_{q\bullet}$ and m_q close to those admitted by the S.M., the discrepancies between the obtained values and those of the S.M. being explained by the differences between the two particle models: the S.M. and the CGT's model.

3.4. The Calculation of Values of the Current Quarks' Volumes

Conform to Equations (15)-(17), it also results in CGT, that the values of m_q (specific to bound quarks) vary with the mass of the composite particle which contains these quarks (being smaller to mesons and bigger to baryons and other multi-quark particles.

The volume υ_q of the bound current quark, composed of preonic kernelois (in CGT's model [17]), must have a similar variation but with the inferior limit resulting as a sum of dilated volumes υ_z^a of preonic kerneloids vibrated with an amplitude δ_z, with an apparent radius: $r_k^z = r_z^r\left(T_i^z\right) + \delta_z$, with $r_z^r\left(T_i^z\right)$, the real radius of the z^0-preon dilated by vibrations of quasielectrons' kerneloids, giving an intrinsic temperature T_i^z which, as δ_z, depends on the quark's vibration energy: $k_B T_i^z \sim E_v^q = k_B T_q$.

Because in CGT the volume υ_{qN} of a possible composite current quark: q_N = ($u\bar{u}d$) is approximately equal to the volume of a protonic kernel υ_p, we can approximate the value of $r_k^z\left(T_q\right)$ at an intrinsic temperature $T_Q^j \approx T_n^j$ corresponding to that of a vibrated nucleon with the energy E_n^j ≈ 1 MeV by extrapolating the case of the nucleon's impenetrable volume $\upsilon_n\left(r_i^n\right)$ at nucleon's temperature: T_n^j ≈ 1 MeV/k_B, considered spherical and filled with dilated kerneloids of z^0-preons of its dilated q-quarks, to the case of a composite current quark (tri-quark) at ordinary temperature $T_Q^j \approx T_n^j$, whose kerneloid's mass is:

$m_q^n > 3m_q^{n-1}$ by photons acquiring and with the apparent volume υ_z^a approximated by a relation similar to that specific to a nuclear volume:

$$\upsilon_k^n \approx \upsilon_z^a \cdot N_z^n;\ \Rightarrow \upsilon_k^q \approx \upsilon_z^a \cdot N_z^q;\ \Rightarrow r_k^n \approx r_z^a \cdot N_z^{1/3};\ r_k^q \approx r_z^a \cdot N_z^{1/3} \quad (24)$$

A similar relation is also used in some papers [43], for the strangelet's radius:

$R_s = r_i(A_i)^{1/3}$, r_i being its radius parameter (1 fm—for free stable state) and A_i—the mass number of the strangelet of the i-th specie, considered as spherical particle-like bound state formed as of roughly equal numbers of up, down, and strange quarks [44] and described by a specific drop model.

With: r_i^n = (0.44 - 0.45) fm [30]; $N_z \approx 1836 m_e / 34 m_e = 54$ (for proton), it results by Equation (24) that: r_z^a = 0.118 fm ≈ 0.12 fm (υ_z^a = 0.723 × 10^{-47} m^3), at T_n^j ≈ 1 MeV/k_B, the kerneloid of a protonic u/d-quark having, by Equation (24), at ordinary nucleons' temperature T_n^j, an apparent radius:

$r_q^a = \left(r_q^r + \delta_q\right) = 0.118 \times 18^{1/3} \approx 0.31\ \text{fm}$ (given by its real radius r_q^r ≈ 0.2 fm and its vibration amplitude δ_q).

The apparent value: r_z^a ≈ 0.12 fm being equal to the length l_z^0 of a cold z^0-preon, it corresponds to a prismatic z^0-preon dilated radially and becoming approximately spherical.

Because the energy E_n^j = 1 MeV of a nucleon, specific to a temperature T_n^j ≈ 1 MeV/k_B = 1.16 × 10^{10} K of the nucleons' network is transmitted to the nucleonic current quarks in the proportion $k_v(m_q/M_n)$; ($k_v \le 1$; m_q/M_n—(current quark mass/nucleon mass)), their specific temperature: $T_q^j = k_v\left(m_q/M_n\right)T_n^j$ can be considered as 'ordinary temperature' for a network of current quarks, for current u/d-quarks resulting: $T_q^j \approx k_v\left(m_{qn}/M_n\right)T_n^j = k_v 9.3\times10^7\ \text{K}$ (~9.3 × 10^7 K with k_v ≈ 1).

Similarly, the quark's vibration generates the inflation of its volume $\upsilon_q(T_z)$ by the vibration energy transmitted to their z^0-preons, corresponding to an intrinsic temperature $T_i^q = T_z = k_v\left(m_z/m_q\right)T_q$, which conform to the CGT's model of particle.

Also, for a bare quark star with high density, the radius r_k^q of the current quark's volume υ_k^q is approximately the minimal radius of the quark's effective mass (reduced to its bare mass by the loosing of the bosonic shell—of "naked" photons, in CGT).

Conform to Equation (24) and the mentioned extrapolation, the radius of the current $s^\bullet$-quark considered in the Standard Model's variant (flavor) ($M_s^\bullet$ ≈ 486 MeV/c^2; N_z = 28), results of value: $r_k^{s\bullet}$ = 0.12 × 3.04 = 0.365 fm, at ordinary temperature T_q^j.

For the CGT's variants of quarks, it results in the next values of r_k^q at ordinary temperature $T_q^j = k_v 9.3\times10^7\ \text{K}$:

The radius of the current s-quark considered in the Souza/CGT' variant (flavor) (M_q ≈ 0.5 GeV/c^2; N_z = 29), results of value: r_k^s = 0.12 × 3.07 = 0.37 fm (at $T_q \approx T_q^j$);

The radius of current v-quark of CGT (~0.574 GeV/c^2; N_z = 33), results of value: r_k^v = 0.12 × 3.21 = 0.385 fm, at $T_q \approx T_q^j$ (*i.e.*, corresponding, by the arrangement specific to **Figure 2**, to a prismatic v-quark dilated more radially than axially, as a consequence of stronger magnetic force between quasielectrons on axial direction, conform to CGT).

The radius of current c-quark considered in the Souza/CGT' variant (flavor) (~1.7 GeV/c^2; N_z = 98, resulting in CGT as a de-excited cluster of three v-quarks in the Souza-CGT' variant), results of value: r_k^c = 0.12 × 4.61 = 0.55 fm, in a spherical form, at $T_q \approx T_q^j$, and corresponds to a quarks cluster dilated more radially than axially; (the high of c-quark in the arrangement specific to **Figure 6** with the real value: $r_z \approx 3 \times 10^{-2}$ fm resulting of value: $h_k^c \approx h_k^v = 6l_z = 0.72\ \text{fm}$).

The radius of a current b-quark considered in the Souza/CGT' variant (flavor) (~5 GeV/c^2; N_z = 288) (resulting in CGT as de-excited cluster of three c-quarks) results by Equation (24) of value: r_k^b = 0.12 × 6.6 = 0.79 fm, at $T_q \approx T_q^j$, in CGT; (with the same arrangement of **Figure 6**, but as formed by current c-quarks, corresponding to a quarks cluster dilated more radially than axially).

3.5. The Justifying of the CGT's Calculation of Current Quark's Volume

A supplementary justification of the current quark's radius: r_q^n ≈ 0.2 fm used in CGT for the real volume of a dilated current mass of a u/d-quark of a nucleon having an ordinary temperature T_n^j ≈ 1 MeV/k_B, instead of the value: $r_q^\bullet$ = 0.43 × 10^{-3} fm, actually considered by the S.M., is the next:

The known MIT bag model considers the current quarks and the gluons as light particles with a radius $r_q^\bullet$ < 10^{-3} fm moving inside a „bag" volume of radius R ≈ 1 fm, with the normal component of the pressure exerted by the free Dirac particles inside the bag balanced at the surface by the difference in the energy density of the quantum vacuum inside and outside the bag: $\Delta E = (4\pi/3)B \cdot R^3$, corresponding to 1/4 of the nucleon's rest energy, with B ≈ 58MeV/fm³ [45], the B-constant having the meaning of a quantum vacuum pressure. Conform to this model, the quark confinement is explained by a potential similar to the Cornell potential: $V_{qC} = -\frac{k_1}{r} + k_2 \cdot f(r)$ (with a pseudo-Coulombian term of color charges interaction by gluon exchange and a strong force term corresponding to an elastic force as that generated by an elastic string formed between a pair of quarks), but with the second term in the form: $B \cdot V = (4\pi/3)BR^3$, *i.e.* by a pressure force on the bag's surface: $F_t = 4\pi BR^2$, with B ≈ 58MeV/fm³ = 9.28 × 10^{33} N/m². But for a current quark with a supposed radius $r_q^\bullet$ = 0.43 × 10^{-3} fm, the resulting B-value gives a specific force: $F_q^\bullet = \pi r_q^{\bullet 2} \cdot B = 5.39 \times 10^{-3}$ N of very low value.

If a nucleon has a vibration energy E_v = 1.4 × 10^{-13}J = 0.875 MeV, corresponding to a nuclear temperature T_n' ≈ 10^{10} K, the energy E_q transmitted to a current quark of mass m_q ≈ 3 MeV/c² is: $E_q = (m_q/m_n)E_v$ = (3/938)0.875 = 0.0028 MeV ≈ 4 × 10^{-16} J, much higher than the mechanic work of the force $F_q^\bullet$ (considered constant) on the distance Δr ≈ 1 fm ($L(F_q^\bullet) = F_q^\bullet \Delta r \approx 5.4 \times 10^{-18}$ J), which lead to the conclusion that the current quark could penetrate the bag's surface even at an ordinary nuclear temperature T_n^j, without the interaction with the other two quarks by "color charge" (a concept not enough explained micro-physically), resulting that the $F_q^\bullet$-force cannot explain the current quark's "asymptotic freedom" with $r_q^\bullet$ = 0.43 × 10^{-3} fm.

However, the B-constant corresponding to the CGT's bag model [16], is given by radially kinetized, naked' photons (*i.e.* photons reduced to their inertial mass: $m_f = h\nu/c^2 \geq m_h$, contained by the photon's kerneloid, of radius $r_f < 10^{-17}$ m and volume υ_f), which are radially vibrated at the surface of the "impenetrable" volume of nuclear interaction $\upsilon_i(a_i)$, considered of a radius a_i ≈ 0.6 fm (used in the Jastrow's expression for the nuclear potential [46]), as consequence of the vortical field's attraction by a scalar potential of the form (1); (16) (with υ_f instead of υ_i), the generated bag's potential being considered as resulting by a Gaussian variation of the kinetic energy density of vibrated photons.

Its value is given in CGT by the conclusion that, at the quarks deconfining temperature

$T_d \approx 2 \times 10^{12}$ K [47], considered as corresponding to the compressed nucleons, the mechanic work of the mean force $F_q(r) = -\nabla V_{qn}$ must cancel the kinetic energy $E_{qv} = (m_q/m_n)E_D$ obtained by a current (u/d)-quark, until the bag's surface ($r_i = a_i \approx 0.6$ fm), *i.e.*:

$$E_D = \frac{1}{2}m_n v^2 = k_B T_d = \frac{m_n}{m_q}\left(V_{qn}\left(r_i\right) - V_c^*\right) \approx \frac{m_n}{m_q}V\left(r_i\right) = 175\ \text{MeV};$$
$$V\left(r_i\right) = \vartheta_q \cdot P_{si}^0\left(a_i\right) = \frac{\upsilon_q}{2}\rho_f\left(r_i\right)c^2 \tag{25}$$

($\upsilon_q = \upsilon_q(0.2\ \text{fm})$—the current quark's volume, in CGT, in concordance with older experiments), $P_{si}^0\left(a_i\right) = 1/2\Sigma\rho_k\left(a_i\right)v_f^2 \approx 1/2\rho_f\left(a_i\right)c^2$, being the bag's pressure, with $\rho_f(a_i)$—the density of vibrated naked photons mixed with "quantons" ($E_h = h\cdot 1$), radially kineticized toward the nucleon's center ($v_f \uparrow\downarrow r$).

By the current d-quark's mass $m_d \approx 7.5\ \text{MeV/c}^2$ (more plausible in CGT than the value: $m_d \approx 5.2\ \text{MeV/c}^2$—actually used in the Standard Model), from Equation (25), neglecting the centrifugal potential V_c^* (much lower than V_{qn}—being given in CGT by the nucleonic magnetic moment's vortex), it results by (25): $P_{si}^0\left(a_i\right) \approx 1/2\rho_f\left(a_i\right)c^2 = 6.69 \times 10^{33}\ \text{N/m}^2$, corresponding to: $B \approx 42\ \text{MeV/fm}^3$, for $v_f \uparrow\downarrow r$, so, an acceptable value that can explain the current quark's retaining inside the nucleon's "bag" of a_i—radius until the deconfining temperature T_d, without the concept of "color charge" and also explaining the nuclear force between nucleons [16].

Also, the fraction $1/2\Sigma\rho_k(a_i)$ of the "naked" photons radially kineticized with $v_f \uparrow\uparrow r$, reflected at the surface of the current quark's "impenetrable" quantum volume, can partially explain in CGT the scalar repulsive charge q_s of the current quarks that impedes their fusion at ordinary nuclear temperatures, in concordance with the known "Pauli repulsion" [19], resulting also its dependence: $q_s = q_s(B)$, the value of B resulting, by Equation (16), as proportional to the mass of the particle's kerneloid (and particularly—to the current quark's mass) and to its intrinsic temperature T_i (that partially disturbs the kerneloid's vortical field, diminishing the attractive V_s—potential of the form (1) by increasing the static quantum pressure), in CGT, *i.e.*: $B = \left(m_P/m_n\right) \times \left(T_i^n/T_i\right)B_n$ with m_n; B_n—the nucleon's mass and bag constant and $T_i^n = T_q^j \approx k_v 9.3 \times 10^7$ K—the nucleon's internal temperature given by its current quarks considered of mass $m_{u/d} \approx 7.5\ \text{MeV/c}^2$ at a nucleon's vibration energy $E_v^n \approx 1$ MeV, in case of the nucleon's impenetrable quantum volume ("kerneloid"—in CGT).

3.6. The Similitude between the Quark Models of CGT and of S.M.

The conclusion that the bosonic shell of the current quarks is a photonic one is in concordance with the fact that all charged particles emit photons and with the upper limit for the gluon's mass experimentally determined: 1 - 1.3 MeV/c^2 [6], approximately equal to that of an (e^-e^+) pair.

It is also possible to make a similitude between the S.M.'s quark model, supposing a valence current quark and a shell of qluons conceived as (q-$\bar{q}$)-pairs which interact by the color charge of the paired quarks and which generate an anti-screening effect that increases the strong force over an adjacent current quark, and the CGT's model of quark formed by a kernel of z^0-preons and an un-paired charged quasi-electron that gives its electric charge $e^* = (2/3)e$, surrounded by a photonic shell.

Supposing that at a critical temperature $T_c \to T_d$ (T_c—phase transformation temperature; T_d—the quarks deconfining temperature: ~2×10^{12} K) some paired kerneloids of paired quasi-electrons (gammons' in CGT [10]-[12]) are released and transferred from the quasicrystalline cluster of its kerneloid in the volume of its photonic shell, then their behavior will be relatively similar to that of the polarised gluons in S.M., with the difference that these ‚gammons' will interact by electric and magnetic interactions (having the tendency to form clusters with 7 or 8 quasielectrons at $T \to 0$ K) but being maintained inside the constituent quark's volume by force generated by a potential of the form (1), *i.e.* by the total vortical field of the current quark (Equation (16)).

After partial deconfining of a current quark, it's confining at $T < T_c$ could generate a quasi-crystal or amorphous state, similar to the so-named, glasma' in the S.M. [48] [49], with the difference that this state is considered in S.M. as specific to a saturation state in high energy hadronic collisions and not to a low temperature quarcic state.

For the S.M.'s quark model, it results in the possibility of explaining, as in CGT, the forming of heavy quarks as tri-quark clusters of lighter quarks having a current mass higher than the sum of masses corresponding to the lighter current quarks of its structure by the addition of a part of gluons of its gluonic shell, *i.e.* by an amorphous of quasi-liquid state of its current mass.

4. The Structure and the Density of a Cold Quark Star, in CGT

It is considered that a cold and dense quark matter might be realized as a new branch of ultra-dense hybrid compact stars, named "charm stars", and that such stars are unstable under radial oscillations [50].

Also, it was concluded [50] that when the strange chemical potential μ_s crosses the charm quark threshold, the following weak equilibrium reaction is allowed to take place:

$$u + d \leftrightarrow c + d \ ,$$

yielding the condition: $\mu_c = \mu_u$, the electric charge neutrality condition being satisfied by the participation of free muons, which appear when $\mu_\mu > m_\mu c^2 = 105.7$ MeV and the lepton number conservation allows the equality: $\mu_\mu = \mu_e$.

According to CGT, because a mass variant (flavor) of c-quark can result in as cluster of three strange quarks [17], a cold charm star could be stable at low temperatures $T \to 0$ K concordant to the semi-empiric equation for the lifetime of mesons and baryons [9] [10], which takes into account the fact that the majority of the elementary baryonic astro-particles (with $n = 3$ quarks) have a lifetime $\tau_B \approx 10^{-10}$ sec. and the majority of mesons ($n = 2$) have a lifetime $\tau_m \approx 10^{-8}$ sec. at an ordinary temperature: T_m = 300 K of the particles' environment, and considering its dependence on the intrinsic vibration energy ε_v of the component current quarks, which, according to CGT, generate a partial destruction of the particle's intrinsic vorticity, with the loss of a part: Δm_p of internal "naked" photons which give the mass of the quark's shell (as in case of a nucleus "hot" forming from nucleons), *i.e.* with: $\tau_k \sim 1/m_P(T)$, giving:

$$\tau_k = \frac{\tau^0}{k_v \cdot 10^{2n}} \approx \frac{\tau^0 m_p}{\Delta m_p(T)}; \quad \tau^0 \approx 3\times10^{-14}\ \text{sec.}; \quad k_v = \frac{\varepsilon_v}{\varepsilon_v^0} = \frac{n\cdot\nu_c}{\nu_c^0} = \frac{n\cdot T}{T_N} \qquad (26)$$

in which: ν_c^0 represents the critical frequency of the phononic energy ε_v^0 of quark' vibration at which the proton's disintegration takes place: $\nu_c^0 = \nu_c\left(T_N \approx 2\times10^{12}\ \text{K}\right) \approx 4\times10^{22}\ \text{Hz}$.

Equation (26) may explain the fact that the heavy baryons with composite heavy quarks can have a longer lifetime at $T\to0$ K but cannot have a long life at an ordinary temperature $T_n^j \approx 1\ \text{MeV}/c^2$ of its vibration, in a free state.

However, inside the core of a neutron star, the stability of tri-quark clusters (including and the composite quarks) may be higher because of the gravitationally generated pressure.

For the d-quark with current mass $m'_d = 7.5\ \text{MeV}/c^2$, the corresponding density: $\rho_d = 4\times10^{17}\ \text{kg/m}^3$ obtained in CGT for $T_q \approx T_q^j$ is concordant with the theoretic conclusion that a neutron star has overall densities of 3.7×10^{17} to 5.9×10^{17} kg/m^3 (varying from ~10^9 kg/m^3 in the outer crust up to (6 - 8) × 10^{17} kg/m^3 in its center) and with the observation that when densities reach a nuclear mean density of 4×10^{17} kg/m^3, a combination of strong force repulsion and neutron degeneracy pressure stops the neutron star's contraction (because the relative incompressibility of nuclear matter) for a stellar mass $M_S < 1.5M_\odot$ [51] ($M_\odot$, solar mass), for more massive neutron stars the ce being contracted until the central density reaches about twice the neutron's saturation density $\rho_n \simeq 2.8\times10^{17}$ kg/m^3, after that, it is generating a shock wave which eventually ejects the outer layers of the star.

Conform to CGT's model of quark [12] [13], the previous observations are explainable by the conclusion that inside the central part of a neutron star, the neutrons are initially reduced to their kerneloids formed by current u/d-quarks, the need for a higher gravitation force $F_g(\rho)$ for the transforming into quark star with higher density being given by the fact that the forming of heavier composite quarks by current u/d-quarks' fusion imply the equality $F_g(\rho) = \text{d}P/\text{d}r$ with the pressure P given by the current quarks' kinetic energy and by the pressure of quanta (photons, in CGT) that generates their "bag" constant B, conform to the known equation of state $P(\rho)$, generating also their repulsive pseudo-charge q_s.

This indicates logically a compactness of the neutron matter corresponding to Equation (24) and to an increasing of the d-quark's mass and density, specific to the forming of a bare quark star, by the transforming of some nucleonic quarks into heavier quarks.

But in CGT, neutronic quarks may result in "strange" anti-quarks (rather than s-quarks), which can be formed from neutronic u-, d-quarks, by a reaction different from that of Equation (25), which in CGT can result in concordance with **Figure 2**, by the sum rule, *i.e.*:

$$N_e(2d+u)\rightarrow\overline{s^-}+\lambda^-;\ \left(d^-+u^+\rightarrow j^+\rightarrow\overline{s^-}+z_\pi;\ d^-+z_\pi\rightarrow\lambda^-\right) \quad (27a)$$

which shows that a neutron can be transformed even at $T\rightarrow 0$ K into a pair formed by a strange antiquark (of electric charge +1/3*e*) and a lambda-quark (lark, specific to CGT, of charge −1/3*e* [9]-[12]), by the fusion of an u-quark with a d-quark and the forming of an intermediary metastable anti-quark ($j^+=\overline{j^-}$ anti-jark, possible in CGT), which is de-excited by emission of a z_π-bosonic preon; (at the surface of a neutronic star, this quarks' fusion being impeded by a tiny repulsive shell giving a quark's repulsive scalar pseudo-charge q_s, conform to CGT).

The reaction (27a) can also result in "at cold", at $T\rightarrow 0$ K, conform CGT, by the conclusion that the current quark's repulsive shell δ_q and its scalar repulsive charge q_s, decreases proportional to the temperature's decreasing.

Theoretically, it is possible that the variant:

$$N_e(2d+u)\rightarrow\overline{s^+}+\lambda^+;\ \left(d^-+u^+\rightarrow j^+\rightarrow\lambda^++r^-;\ d^-+r^-\rightarrow\overline{s^+}\right) \quad (27b)$$

i.e. by the forming of antiquarks $\overline{s^+}$, with a q-charge of (−2/3)*e*, but it is less probable (the theoretically resulting r^--quark being un-stable).

So, the results conform to Equation (27) the possibility of a "mesonic star" forming because the pair ($\overline{s}$ + λ^-) corresponds as structure to a meson having almost the same mass as a neutron (M_N = 939 MeV/c²) but with a heavier kernel, formed by heavier current quarks, the hypothetical "strange star" resulting in CGT rather as hybrid star, formed by s-antiquarks and lambda-quarks.

In their turn, the resulting mesons (convenient notation: $N_\pi\left(\lambda^-\overline{s}\right)$) can form couples which are equivalent to neutral tetra-quark particles (or octo-quark particles) with mass ~1877 MeV/c² (respective: 3754 MeV), but as a network of current quarks λ^-; $\overline{s}$—in the quark star's case.

Conform to Equations (17); (24), the kerneloid's mass and radius to these particles, at $T_q\approx T_q^j$ are of values: $m_q(2N_\pi)$ = 1409 MeV; $\upsilon_n(r_q$ = 0.57 fm) = 0.775 × 10^{-45} m³ (respective: $m_q(8N_\pi)$ = 3281 MeV; $\upsilon_n(r_q$ = 0.72 fm) = 1.56 × 10^{-45} m³).

So, a quark star formed only by strange quarks or bottom quarks is less probable, conform to CGT, a tetra-quark star being more probable.

Regarding the neutron star's cooling mechanism, according to Burrows & Lattimer (BL86) model, after 20 - 30 seconds after birth, electronic and muonic neutrinos leave the neutron star carrying heat and entropy and cooling the star to a temperature around 1 MeV/k_B [27].

Conform to CGT, during the period of transition to a quark star, the cooling process is continued by emission of a high part of photons which (in the CGT's model) give the mass of the bosonic shell of the neutron's valence quarks, which remain thermalized, with a temperature $T_q\le T_q^j$, because the reducing of the spaces between these current quarks in the central part of a neutron star will generate a gradient of photonic pressure which will expel photons outside the star's surface, the vibration amplitude of the remained current quarks and the local temperature and pressure being reduced.

It is understood that, in this case, the density of such a quark star is given by the density of the component current quarks and not by the density of their constituent quarks (resulting in a bare quark star).

Regarding the current quarks' density, the previous values of r_k^q, obtained by Equation (24), correspond to the next volumes of current quarks (in 10^{-45} m^3) at ordinary temperature T_q^j, which may be considered approximately equal to the minimal radius of the effective mass of these quarks reduced to their current mass inside a quark star, by the gravitation's pressure:

$\upsilon_{u/d}$(0.2 fm) ≈ 0.0335 fm^3; υ_s(0.486 fm) ≈ 0.2 fm^3; υ_s(0.5 fm) ≈ 0.212 fm^3;

υ_v(0.574 fm) ≈ 0.239 fm^3; υ_c(1.7 fm) ≈ 0.696 fm^3; υ_v(5 fm) ≈ 2.064 fm^3.

The mean densities of the mentioned current quarks of Souza/CGT's variants, resulting as specific to a compactness corresponding to a relative cold quark star ($T_q \approx T_q^j$), have, in this case, with: m_d = 7.5MeV/c^2 and: ($m_s^\bullet$ = 91; m_s' = 104; m_v' = 158; m_c' = 1233; m_b' = 4527) MeV/c^2 (obtained by Equation (17)), the values: $\rho_k^{s\bullet} = 0.8\times10^{18}$; $\rho_k^s = 0.87\times10^{18}$; $\rho_k^v = 1.17\times10^{18}$; $\rho_k^c = 3.15\times10^{18}$; $\rho_k^b = 3.9\times10^{18}$ [kg/m^3].

Because for the *v*- and *c*-quarks of Souza/CGT variant, we have the approximate relation (4) ($M_c' \approx 3M_v$), conform to Equation (16), we must have:
$\rho_k^c < 3\rho_k^v$, this relation being satisfied by the obtained values of ρ_k^v and
$\rho_k^c = 2.69\rho_k^v$.

Also, it results that even if we also have, by Equation (16), the approximate relation: $M_b' \approx 3M_c'$, the difference between the maximal possible densities: ρ_k^c and ρ_k^b is considerably smaller: $\rho_k^b \approx 1.24\cdot\rho_k^c$, so we can consider the value: $\rho_k^b = 3.9\times10^{18}$ kg/m^3 as close to the saturation mean value for the heavy current quarks density at $T_q \approx T_q^j$.

For the top, quark ($M(t) = 7 \times 5M(b)$, in CGT), its kernel results approximately as hexagonal polyhedron having the minimal radius: $r_k^t \approx 3r_k^b = 2.37$ fm and a high: $h_t \approx 10r_k^b = 7.9$ fm, at T_q^j.

The mass difference $\Delta M_t = \left(M_t - m_t^\bullet\right) \approx 2$ GeV/c^2 ($m_t^\bullet = m_{tSM} \approx 173$ GeV, compared to: m_t = 174.5 GeV/c^2, given by Equation (17)) is explained as in the case of the other quarks, by the conclusion that a part of the photonic shell Δ_b was included in the current quark's volume, corresponding to a quantity: (Δ_b × 35 – 2000)/35 = 416 MeV/c^2 per b-quark (that represents $\delta\Delta_q \approx$ 8.3% of its current mass) and to a saturation mean density of value: $\rho_k^t \approx \left(1+\delta\Delta_q\right)\rho_k^b = 4.2\times10^{18}\ \text{kg/m}^3$ at $T_q \approx T_q^j$. The link between the black hole and the top quark is also indicated by Ref. [52] regarding their production.

The obtained values for the mean density of current quarks at $T_q \approx T_q^j$ (ρ_k^q = (0.8 - 4.2) × 10^{18} kg/m^3), can also be specific to the density of some quark stars having the same ordinary internal temperature T_q^j and formed inside a neutron star for which the necessary pressure for its forming is given by the gravitation force and the strong force (given by Equation (1), in CGT), the compactness of the current quarks' network conforming to Equation (24), the bosons of the quarks' shell Δ_q (of photons, in CGT) remaining partially inside the spaces between the volumes υ_k^q of the current quarks m_q.

It is observed that for bigger quarks/particles ($M_q \gg M_s$), we have: $M_s/M_q \to 0$ and $\Delta_q \to \Delta_q^M = A_q e^k \approx 474$ MeV/c^2, *i.e.* Δ_q is limited to a maximal value, Δ_q^M, Equation (17) becoming with Δ_q = constant, as in Equation (13) of the S.M.

Taking into account also Equation (27a), for the considered tetra-quark and octo-quark particles identified as components of a quark star, by the calculated values for m_q and υ_q it results in the density:
$\rho_k^q \approx \rho_k^q(2N_\pi) = m_N/\upsilon_{iN} = 1409\ \text{MeV}/0.775\times10^{-45}\ \text{m}^3 = 3.23\times10^{18}\ \text{kg/m}^3$, and respective:
$\rho_k^q \approx \rho_k^q(4N_\pi) = m_{2N}/\upsilon_{2N} = 3281\ \text{MeV}/1.56\times10^{-45}\ \text{m}^3 = 3.74\times10^{18}\ \text{kg/m}^3$, at $T_q \approx T_q^j$.

These values are around the value: $\rho_k \approx 3.45 \times 10^{18}$ kg/m^3 obtained as density in the center of the pulsar PSR J1614-2230 [53].

The hypothesis looking at the possibility of quark stars forming by quarks with a mass/density comparable to that of a top quark can result from Equation (27) by the heavy clusters' forming of current quarks λ^+ and $\overline{s^+}$ magnetically coupled and by the strong force in structures of types:

$$S_{q^-} = 4.5N_\pi \to \left[\left(\lambda^- + \overline{s^-} + \lambda^-\right) + \left(\overline{s^-} + \lambda^- + \overline{s^-}\right) + \left(\lambda^- + \overline{s^-} + \lambda^-\right)\right]^- \quad (28a)$$

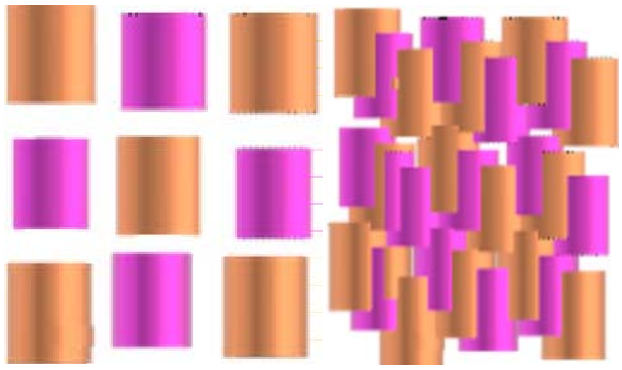
$$S_{q^-} = 4.5N_\pi \to \left[\left(\overline{s^-} + \lambda^- + \overline{s^-}\right) + \left(\lambda^- + \overline{s^-} + \lambda^-\right) + \left(\overline{s^-} + \lambda^- + \overline{s^-}\right)\right]^+ \quad (28b)$$

i.e. formed by tri-quark clusters: $C^-(\lambda^- \text{-} \overline{s^-} \text{-} \lambda^-)$ and $C^+(\overline{s^-} \text{-} \lambda^- \text{-} \overline{s^-})$, corresponding to a constituent mass: M(C) = (1374; 1443) MeV/c^2, which can form S_q-layers: $C^+C^-C^+$ and $C^-C^+C^-$, *i.e.* corresponding to the forming of a heavy quark (named by us "stark", quark of quark stars) with a q-charge of $(-1/3)e$ and a constituent mass: $M(\overline{S}_q) = 4M_n + M_{\lambda,S}$ = (4191; 4260) MeV/c^2 (**Figure 7(a)**), this composite quark having a structure relative similar to that of a bottom quark in Souza/CGT variant (with constituent cold mass: M_b = 5204 MeV/c^2 and the mass of its de-excited state: ~5000 MeV/c^2) and corresponding approximately to Equation (4).

Clusters of three current S_q-quarks: $H_q^\pm = \left(S_q \overline{S}_q S_q\right)$; $\left(\overline{S}_q S_q \overline{S}_q\right)$, *i.e.* corresponding to a constituent mass: $M(H_q)$ = (12,642; 12,711) MeV/c^2 and (by Equation (17)) to a current mass: m_H = 12,313 MeV/c^2, can also be formed, in our opinion, as current $H_q^\pm$-quarks (**Figure 7(b)**).

So, the results conform to CGT that also a quark star formed by heavy quarks with mass close to that of a bottom quark but also by quarks three times heavier could be a stable star at low temperatures ($T_q \le T_q^j$), by a (quasi)crystalline network of current quarks.

The density of these current non-de-excited H_q-quarks results by Equations (17) and (24), at $T_q \approx T_q^j$, of value: $\rho_H = m_H/\upsilon_{iH}$ = (12,313 MeV/c^2)/5.295 × 10^{-45} m^3 ≈ 4.13 × 10^{18} kg/m^3.



(a) (b)

Figure 7. The forming of S_q- and B_q-current quarks as clusters of λ^-- and $\overline{s^-}$ -quarks.

It is understood that bigger clusters D_q (quark "nuggets") of paired current quarks λ^- and $\overline{s^-}$, specific to a relative cold quark star, can be stably formed conform to the equation: $D_q = n^3 C_q$ ($n > 3$), but in conditions also depending to the mother star's mass and temperature. This conclusion could also explain the detection of some very heavy particles (of "oh-my-God" type, with mass: ~3.2×10^{20} eV [54]), in our opinion.

The previous conclusions are in concordance with previous results, based on theoretical models for the density variation inside a neutron star, which concluded that the transition from neutron matter to quark matter begins at densities around (1.5 - 4) × 10^{18} kg/m^3 [24], and because this transition implies the forming of a quarks network with a compactness specific to Equation (24), this concordance justifies the calculated minimal values of the current quarks' volumes and the used preonic model of quarks of CGT.

The obtaining of the mentioned values for $\rho_k^q \geq 0.8 \times 10^{18}$ kg/m^3 as specific (at $T_q \approx T_q^j$) to the transforming of current (u; d)-quarks clusters into bound current quarks with upper mass, corresponding to the transition to a quark star, is in concordance with the fact that the density of the current (u/d)-quarks obtained in CGT (~4×10^{17} kg/m^3) is specific also to the value of the surface density of a Strange Quark Star (*i.e.* the density of quark matter at low pressure [20]) and with the conclusion that if a quark matter with strangeness is bound, then energetically it can grow indefinitely by absorbing nucleons (Witten [20]).

Also, the value 0.8×10^{18} kg/m^3—specific to a strange quark star, in CGT, is close to the value: $\rho_{crit} = 0.92 \times 10^{18}$ kg/m^3 obtained by other authors [55], which concluded that the neutron matter transforms into hyperon matter at $\rho > \rho_{crit} = 4\rho_n$ (where ρ_n is the nuclear density).

The use of the obtained minimal values of the current quark's volume for the quark star's density calculated for $T_q \approx T_q^j$ is in concordance with the fact that inside a quark star, the quarks are bound into a quarks network with higher compactness than the quarks bound inside a free particle.

The conclusion regarding the transforming of current (u; d)-quarks into bound

λ-, s-current quarks with upper mass is partially in concordance with the hypothesis of strangelets' forming [20] as bound states of roughly equal numbers of up, down, and strange quarks, small enough to be considered particles, which can convert nucleonic matter to strange matter on contact [56], and which can be cores of "nuclearites" (strangelets with electron shell).

The conclusion that strange (anti)quarks' forming can result, conform to Equation (27), also at cold but at high pressure (inside a cold neutron star), is concordant with the fact that strangelets have been suggested as a dark matter candidate [20], they resulting as stable at very low pressure.

However, even if the obtained values of ρ_k^q are specific to a preonic model of quark, because in CGT the maximal density inside a quark is that of the electron's centroid, estimated as being half of an electronic neutrino with mass ~$10^{-4} m_e$ (mass limit: 60 eV/c^2 [57]) and a radius equal to the quark's radius experimentally determined: 0.43×10^{-18} m, *i.e.* ~$(1.3 - 1.5) \times 10^{20}$ kg/m^3, the density of a quark star transformed into a black hole is limited in CGT to this maximal value, which is estimated in astrophysics for the center of a quark star (10^{18} - 10^{20} kg/m^3 [58]) and which is lower than the values calculated by Quantum Mechanics for the density of a preon star ($\rho_p \geq 10^{23}$ kg/m^3; $R = (10^{-1} - 10^{-4})$ m [59]).

In the previous estimation, we accorded credibility to the experimental result obtained in 1972 by K. Bergkvist, which obtained as the upper limit of the neutrino mass the level of 60 eV, using a spectrometer that had a resolution of 50 eV [57], this value being concordant to the CGT's model of electron and of beta disintegration [9]-[11].

5. The Black Hole's Forming in CGT

5.1. The Explaining of the Tolman-Oppenheimer-Volkoff Limit in CGT

Regarding to the maximal possible density resulting from Equation (17), it is observed that, because for $M_q \geq M_t \gg M_s^{\bullet}$ (486 MeV), it results: $\Delta_{s\bullet} = 395 \cdot e^{0.182} = 473.8$ MeV/c^2 which represents a value neglijible compared to M_q (0.3% from the mass of the top-quark, M_t), the quark star's density is approximately constant and of value: $\rho_k^t = \rho_c \approx \left(M_q / \upsilon_q\right)_t = 4.26 \times 10^{18}\ \mathrm{kg/m^3}$ ($M_q \geq M_t$), this being the maximal density inside a quark star at $T_q \approx T_q^j$, conform to Equation (17) and by Equation (24), obtained by the CGT's model of quark for ordinary temperature $T_q \approx T_q^j$, in the sense that a density increasing at values $\rho_k > \rho_c$ supposes a decreasing of the current quark's volume υ_q, *i.e.* the quark's volume contraction by temperature' decreasing from an ordinary temperature of current quarks (around the value $T_q^j \approx 9.3 \times 10^7$ K, specific also to a cooled neutron star) to very low temperatures $T \to 0$ K corresponding to a "black hole" star resulting from a collapsed neutron star with mass equal to the upper mass limit, but by an intermediary state, of cold quark star.

In this case, conforming to the CGT's model, the z^0-preons of the internal quarks lose their vibration energy, and in this case, in Equation (24), we must take, as corresponding to the maximal density specific to a black hole, their real un-dilated (ultra-cold) volume, corresponding, at 0 K and null internal vibrations, to:

$r_z = r_z^0 = 0.03\ \text{fm}$ and $l_z = l_z^0 = 0.12\ \text{fm}$, *i.e.*, $\upsilon_z^0 = \pi r_z^2 l_z \approx 0.34\times10^{-48}\ \text{fm}^3$ (Chapter 2).

For the case of an intermediary quark star made by current H_q-quarks of CGT ($M_H \approx 12.7\ \text{GeV/c}^2$; $m_H \approx 12.3\ \text{GeV/c}^2$), which is transformed into a black hole, by the previous value of υ_z^0, it results in a maximal density: $\rho_{bh}^0 \approx 8.79\times10^{19}\ \text{kg/m}^3$, at 0 K, *i.e.* corresponding to that of a black hole having a mass $M_S = 0.46 M_\odot$, conform to the known relation of the black hole's density:

$$\rho_{bh} = \frac{3c^6}{32\pi G^3 M^2} = \frac{1.85\times10^{19}}{M^2},\ \left(M \text{ in } M_\odot\right) \tag{29}$$

The maximal density of a black hole resulting from the transforming of a cold quark star made of current masses of top quarks (the heaviest known quark: $M_t = 175\ \text{GeV/c}^2$, in CGT [17]) results by taking into account its current mass deduced in the S.M.:

$m_t = 173\ \text{GeV/c}^2$ (with 0.86% lower than that obtained by Equation (17)) and calculating its density by $\upsilon_z^0 \approx 0.34\times10^{-48}\ \text{fm}^3$ and by Equation (29), resulting that:

$$\rho_{bh}^0 = \left(173\times10^3\ \text{MeV/c}^2\right) : \left(\upsilon_z^0 \times 175\times10^3 / 17.37\right) \approx 8.98\times10^{19}\ \text{kg/m}^3\ .$$

This maximal density, corresponding by (29) to an ultra-cold black hole of mass $M_S^0 = 0.454 M_\odot$, could be specific, in CGT, also to micro-black holes formed from micro-quark-stars in a cold but dense Proto-Universe transformed into a hot Universe by gravitationally confining cold formed quarks and particles, which thereafter generated a hot "big-bang" and Universe's expansion.

Compared to existent theoretic models for the density variation inside a collapsed star, the obtained result is relatively different to that of some astrophysical calculations which, by the compactness limit: $R \geq 2.94\,GM/c^2$ obtained a limit for the mean density of a star's core: $\rho_c^* \simeq 5.80\times10^{15}\left(M_\odot/M_S\right)^2\ \text{g}\cdot\text{cm}^{-3}$ [60] (*i.e.* $5.80\times10^{18}\ \text{kg/m}^3$ for a star's mass: $M_S \approx 1 M_\odot$ and $2.8\times10^{19}\ \text{kg/m}^3$ for $M_S \approx 0.45 M_\odot$). Conform to Ref. [60], a lower density of a quark star's center is specific to $M_S > M_\odot$, by Equations (17) and (24), resulting in:

$$\rho_q = \frac{m_q}{\vartheta_q^a} = \frac{m_z}{\vartheta_z^a M_q}\left[M_q - \Delta_q\right] = \rho_z\left[1 - \frac{A_q}{M_q}\cdot \mathrm{e}^{k_q\cdot\left(1-\frac{M_{S*}^2}{M_q^2}\right)}\right] = \rho_c^0\left(\frac{M_\Theta}{M_S}\right)^2\left[\frac{\text{kg}}{\text{m}^3}\right] \tag{30}$$

with $m_z = 34 m_e$; M_q—constituent quark' mass; $\rho_z = m_z/\upsilon_z^a$ (υ_z^a—apparent volume of z^0-preon's kerneloid at a specific intrinsic temperature of quarks, $T_a^i = T_z$).

Equation (30) indicates that a cold quark star with lower mass favors the forming of heavier quarks and the z^0-preons' density increasing, a phenomenon explainable by the lowering of the internal temperature T_i in the mother—neutron star's center at values corresponding to the cold forming of heavier quarks clusters, favored by the temperature-dependent decreasing of the quark's repulsive pseudo-charge q_s (resulting as in the nucleon's kernel case, conform to CGT), the quark star's transforming into a black hole resulting when ρ_z corresponds to $\rho_c^0 = 1.85\times10^{19}$ kg/m^3, conform to Equations (29) and (30).

With: $\rho_c^0 \simeq 5.80\times10^{18}$ kg/m^3 [60], for the value: $\rho_t = 4.2\times10^{18}$ kg/m^3, specific to a quark star with heavy bottom-like current quarks, Equation (30) gives: $M_S \approx 1.175 M_\odot$, the value: $M_S \approx (1.6 - 1.7) M_\odot$ corresponding, by the same ρ_c^0, to: $\rho_q \approx 2.26\times10^{18}$ kg/m^3.

This value corresponds by Equation (30) to a density between the values: $\rho_k^v = 1.17\times10^{18}$ kg/m^3 and $\rho_k^c = 3.15\times10^{18}$ kg/m^3, *i.e.* to a mix between v-quarks and c-quarks at $T_q^i \approx T_z^j$ (so, conform to CGT, to the c-quarks' forming from v-quarks) and is very close to the density of confined mesonic pairs: $N_\pi\left(\lambda^- \overline{s}\right)$ with $M_N = (935\ \text{MeV/c}^2)$ resulting from neutrons at $T_n \to T_n^j$, conform to Equation (27a) specific to CGT ($\rho(N_\pi) \approx 2.19\times10^{18}$ kg/m^3).

In Ref. [61], by an equation of state (EoS) based on an MIT bag-like model of quark's confining, it was concluded that stars with $M_S \ge 1.7 M_\odot$ are metastable, but in cold stars with $M_S \approx (1.6 - 1.7) M_\odot$ -quarks appear after about 15 s and thereafter, the star's central density increases for a further 15 - 20 s until a new stationary state with a quark-hadron mixed phase core, for stable stars.

However, it has been found [60] that no causal EoS corresponds to a central density (for a given mass) greater than that for the Tolman VII analytic solution [62], which suggests a quadratic mass-energy density dependence on r corresponding to the ansatz:

$$\rho(r) = \rho_c\left[1 - \left(\frac{r}{R}\right)^2\right];\ \rho_c \approx 1.5\times10^{19}\left(\frac{M_\odot}{M_S}\right)^2\left[\text{kg/m}^3\right] \tag{31}$$

with ρ_c—the central density.

It can be observed that this theoretic result of [62], by Equation(31) for $M_S^0 \approx 0.454 M_\odot$, gives: $\rho_c \cong 7.28\times10^{19}$ kg/m^3-value, which is relatively close to that resulting from the CGT's model as maximal density in case of a black hole resulting by the contraction of a t-quark star until T_i = 0K: $\rho_{bh}^0 = 8.98\times10^{19}$ kg/m^3 that corresponds to: $\rho_c \simeq 1.85\left(M_\odot / M_S\right)^2 \times 10^{19}\ \text{kg/m}^3$ by Equation (29).

The difference could be explained by the internal vibrations (which exist even at 0 K—conform to quantum mechanics) which tend to 0 for a black hole's surface at T = 0 K and which at $T \neq 0$, for less dense stars, have significant values not only to z^0-preons, but also to the super-dense centroids of their quasi-electrons, these vibrations determining small inflation of the z^0-preon's volume, even at $T_0 \approx 0$ K, conform to the CGT's model.

So, by according credibility to both results obtained by [60] and [62], it is possible to interpret the difference between these results by Equation (30) as being given by a different degree of current quarks' compactness—generated by different values of internal temperature T_i in the quarcic network of the star (intrinsic quarks' temperature T_q^i generated by z^0-preons' vibrations, corresponding to an

inflated z^0-preon—conform to Equation(24)), because the value:
$r_k^z = r_z^r\left(T_i^z\right) + \delta_z \approx 0.12\ \text{fm}$ was used in Equation (24) as an apparent value, obtained by a radius of the nucleon's kerneloid (of its impenetrable volume):
$r_i^n = 0.44\ \text{fm}$, corresponding to the case of a nuclear network at ordinary nuclear temperature $T_n^j = 1\ \text{MeV}/k_B$, r_i^n decreasing at lower temperatures $T_q^i < T_q^j$.

It must be mentioned that the mass limit that a neutron star can possess before further collapsing into a black hole is not well known. In 1939, by neglecting the nuclear forces between neutrons, using Schwarzchild's equation and an equation of state specific to a highly compressed cold Fermi gas, this mass limit was estimated at 0.7 solar masses—a value representing the initial TOV limit (Tolman–Oppenheimer-Volkoff [63] [64]).

Using an equation of state $P(\rho)$ reduced to: $P = K\cdot\rho^{5/3}$ (polytropic form in the non-relativistic case of a Fermi gas of neutrons), it was found that for a cold neutron core, there are no static solutions and thus no equilibrium between gravitational force and internal repulsive force, for core masses higher than the initial $M_{TOV} = 0.7M_\odot$, the corresponding maximum mass before collapse being with ten percent higher than this ([64]). So, the stars $M_S^0 \approx 0.77M_\odot$ more massive than the TOV limit collapse into a black hole and if the mass of the collapsing part of the star is below the TOV limit for neutron-degenerate matter, the end product is a compact star—either a white dwarf (for masses below the Chandrasekhar limit) or a neutron star or a (hypothetical) quark star.

In 1996, by an equation of state (EoS) based on an MIT bag-like model of quark's confining, it was deduced that the upper mass for neutron stars which are not collapsed into a black hole is in a range from 1.5 to 3 solar masses [51].

It can be observed that the density of a black hole corresponding to the initial TOV limit: $M_S^0 = 0.7M_\odot$ (*i.e.* to $\rho_{bh}^0 = 3.775\times10^{19}$ kg/m^3 by Equation (29)) may be explained in CGT as corresponding to a black hole that resulted from the conversion of a cold t-quark star with current top quarks formed as compact clusters of z^0-preons with inflated volume to a mean apparent value:
$\upsilon_z^a = m_t / \left(\rho_{bh}^0 n_z\right) = 0.8\times10^{-3}\ \text{fm}^3$ (instead of 0.34×10^{-3} fm^3), that corresponds—in spherical model, to a radius: $r_z^s = 0.058\ \text{fm}$, and in a prismatic (cold) form—to an inflated volume: $\upsilon_z^i = \pi\left(3r_{ie}\right)^2\left(12r_{ie}\right)$ that corresponds to an apparently inflated volume of the quasielectrons' kerneloid, of radius: $r_{ie} = 1.33 \times 10^{-2}$ fm, given by "zeroth" vibrations of amplitude: $\delta r_{ie} = \left(r_{ie} - r_{ie}^0\right) = 0.33\times10^{-2}\ \text{fm}$.

Supposing that a black hole corresponding to $M_S^0 = 0.7M_\odot$ results by Equation (28), from a quark star composed of current quarks $H_q \pm (12{,}700)$ with current mass: $m_H = 12{,}313$ MeV/c^2, it results in similarly that its density ρ_{bh}^0 is explained by an inflated volume: $\upsilon_z^i = 0.793\times10^{-3}\ \text{fm}^3$ (very close to the previously obtained value: 0.8×10^{-3} fm^3).

So, the initial TOV limit $M_S^0 = 0.7M_\odot$ results theoretically in CGT by the fact that the repulsive force of the vibrated z^0-preons and of their quasi-electrons equilibrates the gravitation force by the repulsive scalar (pseudo)charge q_s^z of the z^0-preons' kerneloids having a behavior of impenetrable rest mass volume in a report to identical or similar kerneloids, even at $T \to 0$ K.

Generally, the compact stars of less than $1.44 M_\odot$ (the Chandrasekhar limit) are white dwarfs and compact stars weighing between that and three solar masses should be neutron stars.

The fact that conforms to known studies [51], in the interval: (1.44 - 3) $M_\odot$, both types: neutron stars and black holes may exist (placing the TOV limit in this interval) can be similarly explained by the conclusion that the initial TOV limit: $M_S^0 = (0.7 - 0.77) M_\odot$ corresponds in CGT to a black hole (B.H.) with maximal density given by an intrinsic temperature of quarks: $T_i \to 0$ K but with less inflated z^0-preons, while at higher internal temperatures: $T_i > 0$ K, the inflation (dilation) of the quark's volume is increased as a consequence of z^0-preons' vibration energy ($\varepsilon_z = k_B T_i$), whose amplitude $\delta r_z \neq 0$ gives an apparent radius r_z^i of the inflated volume of these z^0-preons of the same current quarks: $\upsilon_z^i \left(r_z^i \right)$ with $r_z^i = r_z^r + \delta r_z$, these current quarks having, in this case, a volume corresponding to a lower density: $\rho_{bh} < \rho_{bh}^0$ and implicitly, by Equations (29)-(31), to an upper M_S^0—mass of B. H.

Even if the star's density cannot increase over ρ_{TOV} for masses $M_S < M_S^0$, for $M_S > M_S^0$ the gravitation force can maintain or even increase the density of the star's center, because: from the equilibrium equation: $\mathrm{d}P(r)/\mathrm{d}r = -\rho(r) \cdot g(r)$, it is deduced that a higher gravitationally generated pressure could compress the internal core of a massive black hole until a new static equilibrium corresponding to a higher density, the limit resulting in CGT for a black hole composed of electronic centroids with radius $r_0^e \approx 0.43 \times 10^{-18}$ m (also forming electronic neutrinos—in CGT [10]): ~(1.3 - 1.5) × 10^{20} kg/m^3 in CGT.

The results also showed that all stars with $M_S < M_S^0 = 0.7 M_\odot$ have low dilated current quarks and z^0-preons compared to a BH having $M_S = M_S^0$.

5.2. Observations Regarding the Equation of State at the Neutron Star's Cooling

The static equilibrium: $\mathrm{d}P(r)/\mathrm{d}r = -\rho(r) \cdot g(r)$, specific also to the quark stars created in the interval: $M_S^0 \div 3 M_\odot$ ($M_S^0 \approx 0.7 M_\odot$), that is realized between the gravitation force and the pressure gradient specific to the repulsion between compressed current quarks given by their scalar (pseudo)charge (resulting as depending on the bag constant B, in CGT), imply the use of an EoS: $P(\rho c^2)$ that in CGT must take into account not only the current quarks' vibration energy E_q but also the intrinsic temperature of quarks (T_i^q) given by the kinetic energy of the kerneloids of their z^0-preons.

In this case, for a quark star formed by composite current quarks of mass $m_Q = n_q m_q$—given by preonic quarks of current mass m_q, instead of a polytropic form: $P = K \cdot \rho^{5/3}$ of EoS—that does not contain neither the temperature $T_q(m_q)$ nor the internal temperature $T_i^q = T_z(m_z)$, it can be chosen an EoS in the form: $P_i = (\rho_Q / m_q) k_B T_q$ ($\rho_Q(r)$ is the local density), the proportionality $P \sim \rho^1$ being used in EoS specific to high densities, first discussed by Zeldovich [65].

But because the compactness of a quark star composed of composite current quarks with mass: $m_Q > n_q m_q$ results in CGT conform to Equation (24), it results that:

$\rho_q = m_Q / n_z \upsilon_z^i$, with $n_z \upsilon_z^a = \upsilon_Q(T_q)$, the dilated volume of the composite current quark Q (depending on its intrinsic temperature $T_i^Q = T_q$) being given as a sum of apparent volumes υ_z^a of n_z-kerneloids of z^0-preons (dilated by the vibrations of its subcomponents) and as a sum n_q of apparent volumes υ_q^a of dilated current quarks (formed by dilated kerneloids of z^0-preons), *i.e.*:

$$\upsilon_Q(r_Q^i) = n_q \cdot \upsilon_q^a = n_z \cdot \upsilon_z^a, \; (n_q < n_z(Q)), \tag{32}$$

with: $\upsilon_q^a(r_q^a) = \upsilon_q^r(r_q) + \delta\upsilon_q(T_q)$; $\upsilon_z^a(r_z^a) = \upsilon_z^r + \delta\upsilon_z(T_z)$; ($r_z^a = r_z^r + \delta r_z$); (υ_q^r; υ_z^r—the real dilated volume at ordinary intrinsic temperature T_i; $\delta\upsilon_q(T_q)$; $\delta\upsilon_z(T_z)$—the apparent part, given by the kerneloid's vibration amplitude: δr_q; δr_z), resulting that:

$$P_i(Q) = \left(\frac{1}{\upsilon_q^a}\right) \cdot k_B T_q = \left(\frac{n_q}{n_z \upsilon_z^a}\right) k_B T_q; \; (n_z = M_q / M_z) \tag{33}$$

In this case, it is explained the fact that P_i in a quark star formed by dilated composite current quarks depends not only on the temperature T_q (given by the vibrated current q-quarks of its structure) but also on the intrinsic temperature $T_i^q = T_z$ of these current q-quarks.

For a quark star formed as compact network of dilated current quarks of mass: $m_q = n_z m_z$ (formed only as cluster of z^0-preons), in Equation (33), it must be taken: υ_z^a, T_z instead of υ_q^a, T_q, *i.e.*, $P_i(q) = (m_q / m_z \upsilon_q^a) k_B T_z = (1/\upsilon_z^a) k_B T_z$, with: $T_z = k_v T_q / n_z^q = k_v^2 T_n (m_q / M_p) / n_z^q$ ($k_v \leq 1$; n_z^q—the number of z^0-preons contained by the quark q of current mass m_q; M_p—the proton' mass).

If the internal temperature $T_i^q = T_z$ of the current quark q with initial radius r_q^i decreases, it being a cluster of vibrated z^0-preons, it is contracted conform to Equation:

$P_i V_i = K_t T_i$ (K_t-constant) and the quark's volume and radius decrease according to the dilation law specific to metals, for P_i-constant, *i.e.* conform to:

$$\upsilon_q^f = \upsilon_q^0 + \Delta\upsilon_q = \upsilon_q^0 (1 + \alpha_q \Delta T_z) \tag{34}$$

a similar relation resulting in the dilation of the z^0-preon's kerneloid (with $T_i^z = T_e$).

For a composite quark Q, with $\upsilon_Q^0 = N_q \upsilon_q^0 = N_z^Q \upsilon_z^0$ ($N_z^Q = N_q N_z^q$), by Equation (24), taking the apparent volume $\upsilon_q^a(r_k^q = 0.31\,\text{fm})$ of the current u/d-quark, it results:

$$\upsilon_Q(T_q) = \upsilon_Q^0 (1 + \alpha_Q \Delta T_q) \approx N_q \upsilon_q^0 (1 + \alpha_q^a \Delta T_z) \approx N_z^Q \upsilon_z^0 (1 + \alpha_q^a \Delta T_z) \tag{35}$$

But because we have: $T_q = k_v (m_q / M_n) T_n$ and similarly: $T_z = k_v (m_z / m_q) T_q = k_v^2 (m_z / M_n) T_n$, it results by Equation (35) that:

$$(\alpha_Q \Delta T_q) \approx (\alpha_q^a \Delta T_z) \Rightarrow \alpha_Q = \alpha_q^a \frac{\Delta T_z}{\Delta T_q} = \alpha_Q = \alpha_q^a k_v \frac{m_z}{m_q} = \alpha_q^a k_v \frac{1}{N_z^q} \quad (k_v \leq 1) \tag{36}$$

For the quarcic cluster of a nucleon-quasi-equal with that of a possible composite current quark: $q_N = (u\bar{u}d)$, the dilation constant α_q can be approximated by Equation(34) applied to a dilated current u/d-quark of radius: $r'_q \approx 0.2\text{ fm}$, that corresponds to a volume: $\upsilon_q\left(T_z^j\right) = 3.35\times10^{-47}\text{ m}^3$ at an associated temperature of the vibrated nucleon:

$T_n^j = E_N/k_B \approx 1\text{ MeV}/k_B = 1.16\times10^{10}\text{ K}$, *i.e.* to an energy per kerneloid of z^0-preon:

$E_z^j = k_v^2 E_N (3\times7.5\text{ MeV})/938\times54 = k_v^2 0.71\times10^{-16}\text{ J}$, corresponding to an intrinsic temperature: $T_i^q = T_z^j = E_z^j/k_B = k_v^2 T_n^j (3m_{u/d}/M_n n_z) \approx k_v^2 0.515\times10^7\text{ K}$, while the current quark's volume: $\upsilon_q^0 \approx \pi r_q^2 l_q^0 = 0.91\times10^{-47}\text{ m}^3$ ($r_q^0 \approx 0.09\text{ fm}$; $l_q^0 = 0.36\text{ fm}$) corresponds to an intrinsic temperature $T_i^0 = 0$ K (specific to a black hole), resulting, by (34), that:

$\alpha_q = \alpha_q^r = \Delta\upsilon_q/\upsilon_q^0\,\Delta T_i^q = (2.44/0.91)(1/k_v\,0.51)\times10^{-7} \approx (1/k_v)5.2\times10^{-7}\text{ K}^{-1}$.

Also, it results that: $T_i^Q = T_q^j = E_q^j/k_B = k_v T_n^j (m_{u/d}/M_n) \approx k_v 9.27\times10^7\text{ K}$.

Similarly, for the volume of the composite current quark q_N: $\upsilon_Q(T_q; 0.45\text{ fm})$, given as a sum of apparent volumes of its sub-quarks:

$\upsilon_q^a\left(r_k^q = 0.31\text{ fm}\right) = 12.47\times10^{-47}\text{ m}^3 = \upsilon_q^r\left(r_q = 0.2\text{ fm}\right) + \delta\upsilon_q$, we have by (34) (35):

$\alpha_q^a = \Delta\upsilon_q^a/\upsilon_q^0\Delta T_i^q = (11.56/0.91)\left(1/k_v^2\,0.515\right)\times10^{-7} \approx \left(1/k_v^2\right)24.91\times10^{-7}\text{ K}^{-1}$, and by Equation (36):

$\alpha_Q = \alpha_q^a\left(\Delta T_i^q/\Delta T_i^Q\right) = \alpha_q^a\left(k_v m_z/m_q\right) = \Delta\upsilon_q^a/u_q^0 T_q^j = \alpha_q^a k_v/18 = (1/k_v)1.37\times10^{-7}\text{ K}^{-1}$, ($N_z^q = N_z^n/3 = 54/3 = 18$).

Because, for the considered composite quark: $q_N = (u\bar{u}d)$, we have:

$\upsilon_Q^0 = 3\upsilon_q^0 = 2.73\times10^{-47}\text{ m}^3$ and

$\upsilon_Q\left(T_q^j, r_Q \approx 0.45\text{ fm}\right) = 3\upsilon_q^a\left(T_q^j, r_q = 0.31\text{ fm}\right) \approx 37.4\times10^{-47}\text{ m}^3$ corresponding to: $T_q^j = k_v\left(m_q/M_n\right)T_n^j = k_v\times9.3\times10^7\text{ K}$, it results by Equation (36) that:

$$\alpha_Q = \frac{\Delta\upsilon_Q}{\upsilon_Q^0\Delta T_i^Q} = \left(\frac{\upsilon_Q}{\upsilon_Q^0} - 1\right)\Big/T_q^j = 12.7\left(k_v\cdot9.27\times10^7\right)^{-1} = \frac{1}{k_v}1.37\times10^{-7}\left[\text{K}^{-1}\right] \quad (37)$$

By (37), it results in the same value of α_Q that verifies Equations (34)-(36) in concordance to Equation (24), for $k_v \approx 1$ resulting: $\alpha_q^a = 24.67\times10^{-7}\text{ K}^{-1}$;

$\alpha_q^r = 5.2\times10^{-7}\text{ K}^{-1}$ ($T_q^j \approx 9.27\times10^7\text{ K}$; $T_z^j \approx 0.51\times10^7\text{ K}$).

Equation: $\upsilon_Q\left(T_q\right) = \upsilon_Q^0\left(1 + \alpha_Q\Delta T_q\right)$ could be extrapolated also by the S.M.'s nucleon model, in our opinion, by considering a mean internal temperature T_q of the nucleon's cloud of current quarks and gluons.

For a star with $M_S^0 = 0.7M_\odot$ (mean density $\rho_{bh}^0 = 3.775\times10^{19}\text{ kg/m}^3$) that may result from the conversion of a cold t-quark star with current top quarks formed by z^0-preons with inflated volume to a value: $\upsilon_z^f = 0.8\times10^{-3}\text{ fm}^3$ (instead of 0.34 × 10^{-3} fm^3, at $T = 0$ K), Equation (35) gives an increasing of its intrinsic mean temperature: $\Delta T_i^q = \Delta T_z = \Delta\upsilon_q/\alpha_q^a\upsilon_q^0 \approx \Delta\upsilon_z/\alpha_q^a\upsilon_z^0 = 5.48\times10^5\text{ K}$ over 0 K (for $k_v \approx 1$), given by the vibrations of the kerneloids of z^0-preons with energy $E_z \approx k_B T_z$, with $T_{iC} > \Delta T_z$ in the star's center C and $T_i \to 0$ K in its surface S, resulting, as in case of a rotated neutron star, that a black hole must have a dense solid crust colder than the black hole's center.

For another particular example of a neutron star's core that is cooled from $T_n^i = 1.25\times10^8$ K, at 6 × 10³ yr. to $T_n^f = 0.3\times10^8$ K, at 10⁵ yr. [66], considering the phase of the star's core transforming into a quark star, because these nucleon's temperatures T_n correspond to a temperature associated with the u/d-quark's kerneloid vibration: $T_q = E_q/k_B \approx T_n(m_{u/d}/M_n) = (T_q^i \approx 10^6$ K; $T_q^f = 0.24\times10^6$ K) (by $k_V \approx 1$), it results: $\Delta\upsilon_q/\upsilon_q^i = \alpha_q\Delta T_q = 5.27\times10^{-7}\ \text{K}^{-1}\times0.76\times10^6\ \text{K} \approx 0.4$.
$T_z^i = T_q^i/18 = 0.(5)\times10^5$ K.

However, the neutron star's cooling from $T_n^j \approx 1$ MeV/k_B = 1.2 × 10¹⁰ K to: T_n^i = 1.25 × 10⁸ K, generate a current quark's contraction:

$\Delta\upsilon_q = \upsilon_q\left(T_n^j\right) - \upsilon_q\left(T_n^i\right)$ with:

$$\upsilon_q^i\left(T_n^i\right) = \upsilon_q^0\left(1+\alpha_q T_z^i\right) = 0.91\times10^{-47}\left(1+5.27\times10^{-7}\times0.(5)\times10^5\right) = 0.936\times10^{-2}\ \text{fm}^3$$

resulting: $\Delta\upsilon_q = 2.41\times10^{-2}$ fm³.

If the cooled neutron star is formed as a compact network of current u/d-quarks of the same mass as the initial mass, their density will be increased from $\rho_1 = 4\times10^{17}$ kg/m³ to: $\rho_2 = \rho_1(\upsilon_{q1}/\upsilon_{q2}) = 4\times10^{17}(3.35/0.936) = 1.43\times10^{18}$ kg/m³, *i.e.* corresponding to a quark star, as we supposed.

So, it results that the transforming of a quark star with $3M_\odot > M_S > 1.5M_\odot$ into a black hole can be realized by an intermediary cooling step in which the initially existent current quarks are contracted with the simultaneously decreasing of their scalar repulsive pseudo-charge q_s, by the reduction of the z^0-preons' vibrations (vibrations, also existing at 0 K), also for composite quarks and for the nucleon's kernel (whose "bag" constant is reduced, creating the possibility to be formed heavier current quarks, conform CGT).

Also, it results that all black holes having the density conform to Equation (29) and a mass $M_S \geq M_{TOV}$, even if they can have the Hawking temperature at their surface, as preon stars, they have inflated network(s) of z^0-preons, at least in their core, *i.e.* they have an intrinsic temperature $T_z > 0$ K, of value depending on the stage of its collapsing.

To such stars which are still "hot", the gravitation force generates in their central part a high pressure that determines the forced fusion of current nucleon' quarks and their transforming into λ- and $\overline{s}$-quarks and, after that, into heavier quarks specific to CGT: C_q, S_q, H_q, which by cooling and contraction, can obtain a density specific to a black hole, conform to the resulting model.

This conclusion is in concordance with some theoretic models by which neutron stars are predicted to consist of multiple layers with varying compositions and densities [67], and it can be extrapolated for a dense star composed of "nuggets" of confined quarks, with mass $m_P \gg m_H$, which in this case, by its cooling becomes preon star, *i.e.* formed as a network of z^0-preons, because conform to Equation (17) in this case the ratio Δ_q/m_P is enough small to consider by Equations (17) (24) that the resulting density remains (quasi)constant at $m_P \gg m_H$.

Another EoS that can take into account also the current quark's intrinsic temperature T_i^q is that conformed to the "bag" model, also used for the recalculation of the TOV limit of the neutron star's mass, *i.e.* by the static equilibrium relation, which, in a classic (non-relativist) case, is given by:

$$\frac{\mathrm{d}P(r)}{\mathrm{d}r} = -\rho(r)\cdot g(r);\ \left(g(r) = -\frac{Gm(r)}{r^2}\right) \tag{38}$$

and by an EoS: $P = (\Sigma P^f - B) = (1/3)(\rho - \rho_B)c^2$; ($\rho c^2 = \Sigma\rho_f c^2 + B$; $\Sigma\rho_f c^2 = 3\Sigma P^f$), with $\rho_B c^2 = 4B$, ρc^2—energy density of quarks; P^f—pressure due to each quark flavor (u; d; s), which, with a bag constant: $B = 56$ MeV/fm^3, gives: $\rho_B c^2 = 4B = 4 \times 10^{14}$ g·cm^{-3} [20] (neutron star's surface density).

As in the case of a black hole forming from a quark star having M_S close to M_{TOV} [64], the gravitational collapse of stars with $M_S = (1.5 - 3)M_\odot$ is impeded by the repulsive field of scalar pseudo-charges q_s of the z^0-preons' kerneloids and of their quasi-electrons' kerneloids (conform to CGT), given by the "zeroth" vibrations of their super-dense centroids [12].

Because a similar static pseudo-charge q_s can be considered and for nucleon's impenetrable quantum volume of radius $r_i^f \approx 0.6$ fm but also for other composite particles and for quarks, as given by radially vibrated photons in the particle's vortical potential, in CGT (Equation (16)), it results that this pseudo-charge q_s depends on the B-constant's value which can be considered, for all particles, as corresponding to a pressure of photons of the quantum vacuum radially vibrated at the surface of the particle's kerneloid, of value proportional to the particle's constituent mass, m_P—proportionality that explains by Equation (38), and the necessity of a higher star's mass for its transforming into a quark star with heavier quarks.

The expression of $\in_p = \rho c^2 = \Sigma\rho_f c^2 + B = 3P + 4B$ of EoS shows, in correlation with Equation (38), that the gravitation force must equilibrate the quarks' kinetic energy on the radial direction (corresponding to the local temperature but diminished by the bag's pressure), giving the repulsive field of the associated quark's pseudo-charge [16]: $q_s(m_P, T_i) \sim m_P \cdot T_i$, which, conform CGT [16], has a shorter action radius than the attractive vortical field V_Γ, *i.e.*, $r_s \approx \delta_q\left(l_v^z\right) \approx (0.01 - 0.03)\,\mathrm{fm}$ (compared to ~1 fm for the attractive force of current u/d-quark's), the total local energy density $\in_p\rho(r)$ being given by the quarks' energy density and by that of the quantum vacuum's bosons which determines the bag constant's value.

A more general form of EoS: $P = k(\rho c^2 - 4B)$, with k depending on the mass of strange quark m_s and the QCD coupling α_s ($k = 1/3$ for $m_s = 0$ and $k = 0.28$ for $m_s = 250$ MeV/c^2) was used by Jaffe & Low ([68], 1979);

It has also been noticed in [69] that the equation $\in_p = \in(P)$ can be approximated by a non-ideal bag model, in the form:

$$\in_p = aB + bP \tag{39}$$

with a and b—arbitrary constants. Conform to the previous conclusions, in Equation (39), we must take in concordance with Equation (16): $B(m_P, T_i) = K_B \cdot B_m$, with $K_B \sim \left(T_i / T_i^n\right)^{-1} \cdot \left(m_P / m_n\right)$; m_n, B_n—the nucleon's mass and bag constant and $T_i^n = T_q^j \approx 9 \times 10^7\ \mathrm{K}$ (the nucleon's internal temperature at vibration energy of the nucleon: $E_n^j \approx 1$ MeV), resulting in the forming of heavier quarks decreases the pressure P inside a quark star, as indicated by the EoS used by Jaffe & Low [68], and that the increasing of T_i decreases the value of B (by particle's vorticity partial destroying), increasing the value of $P = (\Sigma P^c B)$.

Equations (33) (34) and Equation (39) with $B(m_P, T_i)$ explain the conclusion that the gradually increasing of the star's density ρ_q by its cooling and gravitational contraction determines the forming of composite current quarks formed as tri-quark clusters composed by s^-- and λ^--quarks, conform to Equation (4) with $n \sim P_i$ (heavier clusters as internal pressure increases), this process having contribution also to the star's core cooling by the reducing of the preonic quarks' vibrations and the transferring of a part of the quark's bosonic shell (photonic, in CGT) in their current mass.

It was argued [70] that on the surface of a strange quark star, quarks are confined by short-range strong interactions, while electrons are confined by long-range electromagnetic interactions, generating an electric field up to 10^{17} V cm^{-1} on a length of hundreds of fermis, the normal nuclear matter being expelled and accumulated over the surface, forming a crust of ~10^2 m thickness (the case of bare strange stars), and when the strange star accretes matter, this crust will collapse to trigger a short burst (Alcock *et al.*, 1986 [70]). Also, it was concluded that some discrepancies regarding the properties of radio-pulsars could be avoided if they were solid.

Conform to the previous explanations, it results as possible, in an intermediary stage, a density variation of a quark star formed initially by current u/d-quarks—different than that considered by Equation (31), *i.e.* with a crust formed by current u/d-quarks—colder than the star's core (still "hot", *i.e.* with a lower density, initially).

For example, for a rotated neutron star (RNS), particularly for magnetars, because the effect of the relativist quantum wind generated by photons of the quantum vacuum ($m_f \geq h \cdot 1/c^2$) is similar to that of an electrostatic field which cools a heated metallic wire, it results in CGT that the inner surface of an RNS (considered as being a solid crust formed mainly of Fe-nuclei which have nucleons with a stronger nuclear interaction) is cooled more quickly than the internal core and particularly—electrically charged with a positive charge Q^+ which could explain its intense magnetic field.

Comparing the cooling of a rotated neutron star with a cooling metal drop, it results that, because the star's crust is cooled faster than the star's interior, the formed solid crust (whose ground state corresponds microscopically to a body-centered cubic (bcc) crystal lattice and macroscopically, to an isotropic bcc polycrystal with elastic properties, given and by "nuclear pastas" [71]) is contracted by the aid of the strong forces, given in CGT by a potential of the form (1), these forces $F_n(y) = -\nabla V_n(y)$, generating a superficial tension σ_q which by the aid of the gravitation force $F_g(R)$ equalizes the internal pressure P_i:

$$\Delta P \cdot dV(R) = \sigma_q \cdot S(R); \Rightarrow \Delta P = P_i - G\frac{M(R')}{R'^2}\rho_c(R') \cdot \delta R = \frac{2\sigma_q}{R'};$$
$$\left(\sigma_q = \frac{F_n(y)}{2l_y}; R' = R - \frac{\delta R}{2}\right) \quad (40)$$

(ρ_c, δR—the solid crust's density and thickness; M, R—the neutron star's mass and radius). It results that for the same star's mass M, P_i decreases with R but increases with ρ_c, δR and σ_q. For example, for strangelets, it was considered a superficial tension $\sigma_s \approx 9$ MeV/fm^2 at 0 K [72], but for $n = \delta R/2r_q$ layers of quarks (r_q, the quark's radius), this value is multiplied, and it can explain the analogy with a metallic drop model.

This analogy is concordant with the known fact that if the conversion of neutron-degenerate matter to quark matter is total, the formed quark star can be imagined as a single gigantic hadron bound by gravity rather than by the strong force that binds ordinary hadrons.

The star's density variation remained after neutron star's cooling, supposed of the form (31), can be explained in this case by the conclusion that a lower internal pressure P_i, specific to the star's surface, cannot determine the fusion of the nucleonic current quarks against their mutual repulsion by repulsive q_s-pseudo-charges, that give the density of the neutron star's inner crust of initial R-radius, while at higher P_i—values the fusion of the u/d—current quarks can be realized, resulting current $\lambda/\overline{s}$ -quarks having a higher q_s—pseudo-charge ($q_s(s^+) > q_s(\lambda^-) > q_s(n)$), which by their strong interaction with $F_s(y) > F_n(y)$ increase the star's crust thickness δR and their σ_q-value, resulting the possibility of heavier quarks' forming during the star's cooling, by the increasing of δR and the star's radius decreasing by contraction, the internal pressure being gradually increased and determining the gradually forming of heavier composite current quarks which, in this case, can explain the density' variation of the formed quark star or of a black hole star (for $R_S > R(M_{TOV})$).

6. Conclusions

The presented theoretical conclusions, based on a semi-empiric relation for the current quarks' mass specific to CGT but with the constants obtained by the aid of the Gell-Mann-Oakes-Renner formula and giving values close to those obtained by the Standard Model, showed that by a current quark's volume obtained as a sum of theoretic (apparent) volumes of preonic kerneloids, it results a density of the current quarks: s$^\bullet$, (s), c$^\bullet$, (c), b$^\bullet$, (b) and t (corresponding to both variants: S.M. and CGT) in the range (0.8 - 4.2) × 10^{18} kg/m^3, at ordinary temperature $T_n^j \approx (m_q/M_n)T_n^j$ ($T_n^j \approx 1$ MeV/$k_B = 1.16 \times 10^{10}$ K), as values which could be specific to possible quark stars, in concordance with previous results which concluded that the transition from neutron matter to quark matter begins at densities around (1.5 - 4) × 10^{18} kg/m^3 [24] and with theoretic observations [60] which indicated that also the value of 1 × 10^{18} kg/m^3 is characteristic to a quark star.

Also, the value 0.8×10^{18} kg/m^3, specific to a strange quark star, in CGT, is close to the value: $\rho_{crit} = 0.92 \times 10^{18}$ kg/m^3 obtained by other authors [55], which concluded that the neutron matter transforms into hyperon matter at $\rho > \rho_{crit} = 4\rho_n$ (where ρ_n is the nuclear density).

This concordance can be considered an argument for the conclusion that the quarks are structured particles, resulting as composite particles, in a preonic model of CGT [9]-[12].

Looking at the possible structure of a quark star, by the preonic quark model of CGT, it resulted that the neutronic quarks can generate, inside a relatively cold neutron star, heavy quarks of mass close to that of the quarks charm and bottom in the CGT's variant (flavor) for non-de-excited c- and b-quarks (*i.e.* c*(1717MeV) and b*(5204 MeV)), by the intermediary transforming:

$N_e(2d+u) \to \overline{s^-} + \lambda^-$ and the forming of composite quarks with the structure:

C$^-$(λ^-- $\overline{s^-}$ -λ^-) and C$^+$($\overline{s^-}$ -λ^-- $\overline{s^-}$), respective:

$$S_q^-\left[\left(\lambda^- \text{-} \overline{s^-} \text{-} \lambda^-\right) + \left(\overline{s^-} \text{-} \lambda^- \text{-} \overline{s^-}\right) + \left(\lambda^- \text{-} \overline{s^-} \text{-} \lambda^-\right)\right]^-$$ and:

$$S_q^+\left[\left(\overline{s^-} \text{-} \lambda^- \text{-} \overline{s^-}\right) + \left(\lambda^- \text{-} \overline{s^-} \text{-} \lambda^-\right) + \left(\overline{s^-} \text{-} \lambda^- \text{-} \overline{s^-}\right)\right]^+,$$

the forming of heavier quarks inside a quark star being also possible, conforming to CGT, in the form: $D_q = n^3 C_q$ ($n \geq 3$), but in conditions also depending on the mother star's mass and temperature.

This conclusion is in concordance with some theoretic models by which neutron stars are predicted to consist of multiple layers with varying compositions and densities [67].

The Tolman-Oppenheimer limit: $M_{TO} = 0.7 M_\odot$ for neutron stars can also be explained by the CGT's quark model as corresponding to a minimal volume of the contracted z^0-preon's kerneloid inside a contracted t-quark star (or composed of other heavy composite current quarks) transformed into a black hole. This explanation indicates that the concept of singularity corresponding to a much higher matter's density ($\rho \gg 10^{20}$ kg/m^3) used also by the big-bang model of Universe' expansion, is not plausible.

The resulting conclusion is that a quark star can be formed inside a neutron star at densities of $(0.8 - 4.2) \times 10^{18}$ kg/m^3 by the transforming of nucleonic u-, d-current quarks contained by the nucleon's impenetrable volume of mechanic interaction radius ~0.44 fm (at an ordinary temperature $T_n^j \approx 1$ MeV/c^2 and at high gravitation pressure) into *s*- and λ-quarks of CGT, whose volume is thereafter contracted when their internal temperature T_i^q decreases is in concordance with theoretical observations [21] that collapsed nuclei with mass number $A \geq 16$ - 40 can be formed at enough high pressure also in neutral state, with a radius: $R_C \approx r_c A^{1/3}$ with $r_c \leq 0.4$ fm.

Also, the recent discovery [73] of a possible quark star having a radius of about 10.4 kilometers, a surface temperature of approximately 2×10^{6}°C and a mass equal to only $0.77 M_\odot$ (almost 1.5 times less than the theoretical limit for neutron stars), corresponding to a mean density: $\rho_m = 3.27 \times 10^{17}$ kg/m^3, is in concordance with the conclusion that a such star can have a neutronic inner crust ($\rho_s \approx 2.8 \times 10^{17}$ kg/m^3) and a nucleus formed by current quarks.

It may also be observed a similitude between the CGT's model of quark star forming by mesonic pairs of current quarks λ^-, $\overline{s^+}$ (specific to CGT) and some proposed models of boson star, *i.e.* made of bosons with m_b-mass, as that of Ref. [74] which studied properties of compact stars made of massive bosons with a repulsive self-interaction mediated by vector mesons within the mean-field approximation and which for a boson with QCD-type interaction strength and a boson mass m_b = 100 GeV/c^2 obtained the maximum mass: $M_{\max} \approx 0.3M_\odot$ with a radius $R_b \approx 2$ km, *i.e.* with a mean density of 1.8×10^{19} kg/m^3, with $m_b \approx 1$ GeV/c^2 being obtained: $M_{\max} \approx 1M_\odot$ and $R_b \approx 10$ km, corresponding to a mean density of 4.8×10^{17} kg/m^3 that corresponds in CGT to a relatively contracted nucleonic current u/d-quark.

Also, the intermediary transforming: $N_e(2d+u) \to \overline{s^-} + \lambda^-$ specific to CGT can explain the fact that the experiments of nucleon's quarks deconfining at a temperature limit of ~2×10^{12} K [75] indicated that the matter formed in head-on collisions of gold ions is more like a liquid with very low viscosity than a gas, liquid whose constituent particles interact very strongly among themselves [76], being also determined an initial temperature of the "perfect" liquid of four trillion degrees Celsius [77]. The previously observed "jets" of high-energy quarks and gluons can also be explained in CGT by the forming of (u^+-d^-)-pairs of nucleonic quarks, whose electric charges determine their mutual repulsion.

These theoretical possibilities, correlated with the possibility of explaining the neutron star's core transforming into a quark star in conditions of high pressure, bring arguments for the preonic model of quark specific to CGT. Also, since the expansion of the Universe transports material structures from hotter areas to colder areas, it follows that due to the dilation/contraction of quarks and nucleons, the existence of living structures is possible in a relatively narrow space-time interval relative to the time-space scale of the Universe, life not being possible in areas that are too hot or too cold.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] Patrignani, C. (2016) Review of Particle Physics. *Chinese Physics C*, **40**, Article ID: 100001. https://doi.org/10.1088/1674-1137/40/10/100001

[2] Andersson, B., Gustafson, G., Ingelman, G. and Sjöstrand, T. (1983) Parton Fragmentation and String Dynamics. *Physics Reports*, **97**, 31-145. https://doi.org/10.1016/0370-1573(83)90080-7

[3] Hanson, G., *et al.* (1975) Evidence for Jet Structure in Hadron Production be e+e- Annihilation. *Physical Review Letters*, **35**, 1609-1612.

[4] Perl, M.L., *et al.* (1976) *Physical Review Letters*, **35**, 1489.

[5] Herb, W., *et al.* (1977) Observation of a Dimuon Resonance at 9.5 GeV in 400-GeV Proton-Nucleus Collisions. *Physical Review Letters*, **39**, 252-255.

[6] Ynduráin, F.J. (1995) Limits on the Mass of the Gluon. *Physics Letters B*, **345**, 524-526. https://doi.org/10.1016/0370-2693(94)01677-5

[7] Chipman, D.R. and Jennings, L.D. (1963) Measurement of the Atomic Scattering Factor of Ne, Ar, Kr, and Xe. *Physical Review*, **132**, 728-734. https://doi.org/10.1103/physrev.132.728

[8] ZEUS Collaboration (2016) Limits on the Effective Quark Radius from Inclusive e-p Scattering at HERA. *Physics Letters B*, **757**, 468-472.

[9] Arghirescu, M. (2006) The Material Structures Genesis and Fields Effects. Ed. MatrixRom.

[10] Arghirescu, M. (2015) The Cold Genesis of Matter and Fields. Science P.G.

[11] Arghirescu, M. (2016) A Preonic Quasi-Crystal Quark Model Based on a Cold Genesis Theory and on the Experimentally Evidenced Neutral Boson of 34 Me. *Global Journal of Physics*, **5**, 496-504.

[12] Arghirescu, M. (2018) A Model of Particles Cold Forming as Collapsed Bose-Einstein Condensate of Gammons. *Physics & Astronomy International Journal*, **2**, 260-267. https://doi.org/10.15406/paij.2018.02.00096

[13] Olavi, H. (1961) A Proposed Elementary Particle Theory Based on Interacting Classical Fields. Turun Yliopisto.

[14] Krasznahorkay, A.J., Csatlós, M., Csige, L., Gácsi, Z., Gulyás, J., Hunyadi, M., *et al.* (2016) Observation of Anomalous Internal Pair Creation Inbe8: A Possible Indication of a Light, Neutral Boson. *Physical Review Letters*, **116**, Article ID: 042501. https://doi.org/10.1103/physrevlett.116.042501

[15] Sarri, G., Poder, K., Cole, J.M., Schumaker, W., Di Piazza, A., Reville, B., *et al.* (2015) Generation of Neutral and High-Density Electron-positron Pair Plasmas in the Laboratory. *Nature Communications*, **6**, Article No. 6747. https://doi.org/10.1038/ncomms7747

[16] Arghirescu, M. (2018) The Nuclear Force Explaining by a Bag Model Resulted from a Vortexial, Cold Genesis Model of Nucleon. *Physics & Astronomy International Journal*, **2**, 349-358. https://doi.org/10.15406/paij.2018.02.00109

[17] Arghirescu, M. (2021) An Explanatory Model of Heavy Quarks and Particles Generating Resulted by a Cold Genesis Theory. *Theoretical Physics Letters*, **9**, 190-217.

[18] Cockroft, J.D. (1964) Experiments on the Interaction of High-Speed Nucleons with Atomic Nuclei. Nobel Lectures, 11 Dec. (1951). Elsevier Pub. Comp.

[19] Mullin, W.J. and Blaylock, G. (2003) Quantum Statistics: Is There an Effective Fermion Repulsion or Boson Attraction? *American Journal of Physics*, **71**, 1223-1231. https://doi.org/10.1119/1.1590658

[20] Witten, E. (1984) Cosmic Separation of Phases. *Physical Review D*, **30**, 272-285. https://doi.org/10.1103/physrevd.30.272

[21] Bodmer, A.R. (1971) Collapsed Nuclei. *Physical Review D*, **4**, 1601-1606. https://doi.org/10.1103/physrevd.4.1601

[22] Weber, F., *et al.* (1994) Strange-Matter Stars. In: *Proceedings*: *Strangeness and Quark Matter*, World Scientific, 87.

[23] Chadha, K.S. (2008) Second Supernovae Point to Quark Stars. Astronomy Now Online, June 04, 2008.

[24] George, Y.C.L. (2003) Dense Matter Physics. In: *Encyclopedia of Physical Science and*

Technology, Elsevier, 305-334. https://doi.org/10.1016/b0-12-227410-5/00166-6

[25] Douchin, F. and Haensel, P. (2001) A Unified Equation of State of Dense Matter and Neutron Star Structure. *Astronomy & Astrophysics*, **380**, 151-167. https://doi.org/10.1051/0004-6361:20011402

[26] Kojo, T. (2016) Phenomenological Neutron Star Equations of State. *The European Physical Journal A*, **52**, 51-53. https://doi.org/10.1140/epja/i2016-16051-0

[27] Burrows, A. and Lattimer, J.M. (1986) The Birth of Neutron Stars. *The Astrophysical Journal*, **307**, 178. https://doi.org/10.1086/164405

[28] Dung, D., Kurtscheid, C., Damm, T., Schmitt, J., Vewinger, F., Weitz, M., *et al.* (2017) Variable Potentials for Thermalized Light and Coupled Condensates. *Nature Photonics*, **11**, 565-569. https://doi.org/10.1038/nphoton.2017.139

[29] Milonni, P.W. (1994) Introduction to Quantum Field Theory. In: Milonni, P.W., Ed., *The Quantum Vacuum*, Elsevier, 331-380. https://doi.org/10.1016/b978-0-08-057149-2.50014-x

[30] Islam, M.M. and Luddy R.J. (2013) High Energy Elastic Scattering in Condensate Enclosed Chiral Bag Model and TOTEM Elastic Measurements at LHC at 7 TeV. Talk Presented at the EDS Blois, Sept. 9-13, 2013.

[31] Yan, Y. and Tegen, R. (2001) N-N Scattering and Nucleon Quark Core. *ScienceAsia*, **27**, 251-259. https://doi.org/10.2306/scienceasia1513-1874.2001.27.251

[32] De Souza, M.E. (2011) Calculation of Almost All Energy Levels of Baryons. *Papers in Physics*, **3**, Article ID: 030003. https://doi.org/10.4279/pip.030003

[33] Carrigan Jr., R.A. (1978) Compound Quarks as an Explanation for the Apparent Quark Mass Spectrum. Fermi Nat. Accelerator Lab.

[34] Gell-Mann, M. (1962) Proceedings of the International Conference on High-Energy Nuclear Physics, Geneva, Switzerland.

[35] Okubo, S. (1962) Note on Unitary Symmetry in Strong Interactions. *Progress of Theoretical Physics*, **27**, 949-966. https://doi.org/10.1143/ptp.27.949

[36] Barnes, V.E., Connolly, P.L., Crennell, D.J., Culwick, B.B., Delaney, W.C., Fowler, W.B., *et al.* (1964) Observation of a Hyperon with Strangeness Minus Three. *Physical Review Letters*, **12**, 204-206. https://doi.org/10.1103/physrevlett.12.204

[37] Wood, C. (2022) Inside the Proton, the Most Complicated Thing You Could Possibly Imagine. *Quanta Magazine*, Oct. 19 2022.

[38] Weinberg, S. (1977) The Problem of Mass. HUTP 77/A057.

[39] Banerjee, M.K. (1993) A Chiral Confining Model of the Nucleon. *Progress in Particle and Nuclear Physics*, **31**, 77-157. https://doi.org/10.1016/0146-6410(93)90049-l

[40] Gell-Mann, M., Oakes, R.J. and Rcnner, B. (1968) Behavior of Current Divergences under $SU_3 \times SU_3$. *Physical Review*, **175**, 2195-2199.

[41] Sick, I. (2003) On the Rms-Radius of the Proton. *Physics Letters B*, **576**, 62-67. https://doi.org/10.1016/j.physletb.2003.09.092

[42] Duran, B., *et al.* (2023) Determining the Gluonic Gravitational Form Factors of the Proton. *Nature*, **615**, 813-816.

[43] Wen, X.J., Peng, G.X. and Chen, Y.D. (2007) Charge, Strangeness and Radius of Strangelets. *Journal of Physics G: Nuclear and Particle Physics*, **34**, 1697-1709. https://doi.org/10.1088/0954-3899/34/7/010

[44] Farhi, E. and Jaffe, R.L. (1984) Strange Matter. *Physical Review D*, **30**, 2379-2390. https://doi.org/10.1103/physrevd.30.2379

[45] Johnson, K. (1975) The M.I.T. Bag Model. *Acta Physica Polonica*, **B6**, 865-892.

[46] Jastrow, R. (1951) On the Nucleon-Nucleon Interaction. *Physical Review*, **81**, 165-170. https://doi.org/10.1103/physrev.81.165

[47] Karsch, F., Laermann, E. and Peikert, A. (2001) Quark Mass and Flavour Dependence of the QCD Phase Transition. *Nuclear Physics B*, **605**, 579-599. https://doi.org/10.1016/s0550-3213(01)00200-0

[48] Iancu, E. and Venugopalan, R. (2003) The Color Glass Condensate and High Energy Scattering in QCD.

[49] McLerran, L. (2008) A Brief Introduction to the Color Glass Condensate and the Glasma. *International Symposium of Multiparticle Dynamics*, Hamburg, 15-20 September 2008.

[50] Jiménez, J.C. and Fraga, E.S. (2020) Cold Quark Matter with Heavy Quarks and the Stability of Charm Stars. *Physical Review D*, **102**, Article ID: 034015. https://doi.org/10.1103/physrevd.102.034015

[51] Bombaci, I. (1996) The Maximum Mass of a Neutron Star. *Astronomy & Astrophysics*, **305**, 871-877.

[52] Chamblin, A., Cooper, F. and Nayak, G.C. (2009) Top Quark Production from Black Holes at the CERN-LHC. *Physics Letters B*, **672**, 147-151. https://www.sciencedirect.com/journal/physics-letters-b/vol/672/issue/2

[53] Fatema, S. and Murad, M.H. (2013) An Exact Family of Einstein-Maxwell Wyman-Adler Solution in General Relativity. *International Journal of Theoretical Physics*, **52**, 2508-2529. https://doi.org/10.1007/s10773-013-1538-y

[54] Bird, D.J., Corbato, S.C., Dai, H.Y., Elbert, J.W., Green, K.D., Huang, M.A., *et al.* (1995) Detection of a Cosmic Ray with Measured Energy Well beyond the Expected Spectral Cutoff Due to Cosmic Microwave Radiation. *The Astrophysical Journal*, **441**, 144. https://doi.org/10.1086/175344

[55] Tsuruta, S. (2017) The Temperature of Neutron Stars. 14*th Marcel Grossmann Meeting* (*MG*14), Rome, 12-18 July 2017. https://www.worldscientific.com

[56] Jaffe, R.L., Busza, W., Wilczek, F. and Sandweiss, J. (2000) Review of Speculative "Disaster Scenarios" at RHIC. *Reviews of Modern Physics*, **72**, 1125-1140. https://doi.org/10.1103/revmodphys.72.1125

[57] Bergkvist, K.E. (1972) *Nucl. Phys. B*, **39**, 317.

[58] Rodrigues, H., Duarte, S.B. and de Oliveira, J.C.T. (2011) Massive Compact Stars as Quark Stars. *The Astrophysical Journal*, **730**, 31. https://doi.org/10.1088/0004-637x/730/1/31

[59] Hansson, J. and Sandin, F. (2005) Preon Stars: A New Class of Cosmic Compact Objects. *Physics Letters B*, **616**, 1-7. https://doi.org/10.1016/j.physletb.2005.04.034

[60] Lattimer, J.M. and Prakash, M. (2005) Ultimate Energy Density of Observable Cold Baryonic Matter. *Physical Review Letters*, **94**, Article ID: 111101. https://doi.org/10.1103/physrevlett.94.111101

[61] Pons, J.A., Steiner, A.W., Prakash, M. and Lattimer, J.M. (2001) Evolution of Proto-Neutron Stars with Quarks. *Physical Review Letters*, **86**, 5223-5226. https://doi.org/10.1103/physrevlett.86.5223

[62] Lattimer, J. and Prakash, M. (2007) Neutron Star Observations: Prognosis for Equation of State Constraints. *Physics Reports*, **442**, 109-165. https://doi.org/10.1016/j.physrep.2007.02.003

[63] Tolman, R.C. (1939) Static Solutions of Einstein's Field Equations for Spheres of Fluid. *Physical Review*, **55**, 364-373. https://doi.org/10.1103/physrev.55.364

[64] Oppenheimer, J.R. and Volkoff, G.M. (1939) On Massive Neutron Cores. *Physical Review*, **55**, 374-381. https://doi.org/10.1103/physrev.55.374

[65] Zel'dovich, Y.B. (1961) The Equation of State at Ultrahigh Densities and Its Relativistic Limitations. *Zh. Eksp. Teoret. Fiz*, **41**, 1609.

[66] Ootes, L.S., Wijnands, R. and Page, D. (2019) Long-Term Temperature Evolution of Neutron Stars Undergoing Episodic Accretion Outbursts. *Astronomy & Astrophysics*, **630**, A95. https://doi.org/10.1051/0004-6361/201936035

[67] Baym, G. and Pethick, C. (1975) Neutron Stars. *Annual Review of Nuclear Science*, **25**, 27-77. https://doi.org/10.1146/annurev.ns.25.120175.000331

[68] Jaffe, R.L. and Low, F.E. (1979) Connection between Quark-Model Eigenstates and Low-Energy Scattering. *Physical Review D*, **19**, 2105-2118. https://doi.org/10.1103/physrevd.19.2105

[69] Haensel, P., Potekhin, A.Y. and Yakovlev, D.G. (2007) Neutron Stars 1: Equation of State and Structure. Springer-Verlag.

[70] Alcock, C., Farhi, E. and Olinto, A. (1986) Strange Stars. *The Astrophysical Journal*, **310**, 261. https://doi.org/10.1086/164679

[71] Chamel, N. and Haensel, P. (2008) Physics of Neutron Star Crusts. *Living Reviews in Relativity*, **11**, Article No. 10. https://doi.org/10.12942/lrr-2008-10

[72] Biswas, S., De, J.N., Joarder, P.S., Raha, S. and Syam, D. (2017) Multifragmentation Model for the Production of Astrophysical Strangelets. *Physical Review C*, **95**, Article ID: 045201. https://doi.org/10.1103/physrevc.95.045201

[73] Doroshenko, V., Suleimanov, V., Pühlhofer, G. and Santangelo, A. (2022) A Strangely Light Neutron Star within a Supernova Remnant. *Nature Astronomy*, **6**, 1444-1451. https://doi.org/10.1038/s41550-022-01800-1

[74] Agnihotri, P., Schaffner-Bielich, J. and Mishustin, I.N. (2009) Boson Stars with Repulsive Self-Interactions. *Physical Review D*, **79**, Article ID: 084033. https://doi.org/10.1103/physrevd.79.084033

[75] Karsch, F., Laermann, E. and Peikert, A. (2001) Quark Mass and Flavour Dependence of the QCD Phase Transition. *Nuclear Physics B*, **605**, 579-599. https://doi.org/10.1016/s0550-3213(01)00200-0

[76] McNulty Walsh, K. and Genzer, P. (2005) RHIC Scientists Serve up "Perfect" Liquid. Brookhaven Lab.

[77] McNulty Walsh, K. and Genzer, P. (2010) "Perfect" Liquid Hot Enough to be Quark Soup. Brookhaven Lab.