The structure and the density of a Quark Star in a Cold Genesis Theory of Particles

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Abstract

Based on a semi-empiric relation for the current mass of quarks specific to a Cold genesis theory of particles (CGT) but with the constants obtained with the aid of the Gell-Mann-Oakes-Renner formula and giving values close to those obtained by the Standard Model, by a current quark's volume obtained as sum of theoretic (apparent) volumes of preonic kerneloids, a maximal density of the current quarks: strange (s), charm (c), bottom (b), top (t), resulted in the range $(0.8 \div 4.2)\times 10^{18}$ 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 by the intermediary transforming: $N_e(2d + u) \rightarrow \bar{s}^- + \lambda^-$ and the forming of composite quarks with the structure: $C^-(\lambda^- - \bar{s}^- - \lambda^-)$ and $C^+(\bar{s}^- - \lambda^- - \bar{s}^-)$, and of S_q-layers: $C^+C^-C^+$ and $C^-C^+C^-$ which can form composite quarks: $H_q^{\pm} = (S_q\ \bar{S}_q\ S_q)$; $(\bar{S}_q\ S_q\ \bar{S}_q)$, 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: $D_q = n^3C_q$, $(n \geq 3)$. The Tolman 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, (the Lund 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-l/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 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 explains also the gluons' masses.

In a Cold Genesis pre-quantum theory of particles and fields, (C.G.T., [9-12]), based on the Galilean relativity, it results as more natural alternative the possibility to explain the constituent quarks and the resulted elementary particles as clusters of negatron-positron pairs, named 'gammons' ($\gamma(e^-e^+)$), resulting that preonic bosons and quarks can be formed also 'at cold', as Bose-Einstein condensate of 'gammons' which form quasi-stable basic preons z^0 of mass ~34 m_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 ~34 m_e was evidenced by a research team of Science' Institute for Nuclear Research in Debrecen (Hungary), [14], which evidenced a neutral super-light particle with a mass of ~17 MeV/c^2 , (~34 m_e), named X17, by a reaction:

$$Li7 + p^+ \rightarrow Be^* \rightarrow Be8 + b^0 ; \quad b^0 \rightarrow e^+ + e^- , \qquad m(b^0) \approx 34\, m_e ,$$

which 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 cluster of an even number n = 7x6 = 42 quasielectrons, (integer number of degenerate "gammons", $\gamma^*(e^{*-} e^{*+})$), with mass $m_e^* \approx 34/42 = 0.8095\, m_e$, 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 $\boldsymbol{\Gamma_\mu = \Gamma_A + \Gamma_B}$, 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: ($m_n - m_p \approx 2.62\, m_e$) is given by an incorporate electron with degenerate magnetic moment and a linking 'gammon' $\sigma_e(\gamma^*) = 2m_e^* \approx 1.62\, m_e$, forming a 'weson', $w^- = (\sigma_e(\gamma^*) + e^-)$, which explains the neutron in a dynamide model similar to the Lenard- Radulescu model [9, 10], (negatron revolving around a protonic center by the etherono-quantonic pressure of the proton's $\boldsymbol{\Gamma_\mu}$-vortex with the speed $v_e^* << c$, 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.

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 :

$$V_n(r) = \upsilon_i P_n = V_{n0}\cdot e^{-r/\eta^*}; \quad V_{n0} = -\upsilon_i P_{n0}, \qquad (1)$$

with: $\eta^* = 0.8fm$ (equal to the root-mean-square radius of the magnetic moment's density variation inside a neutron, experimentally determined) and υ_i(0.6fm)- the 'impenetrable' volume of nuclear interaction [9, 10, 16], the nucleon resulting as formed by $N^p \approx$ 54x42= 2268 quasi-electrons which give a proton's apparent density in its center, (given by the sum rule), of value: $\rho_n^o \approx f_c \cdot N^p \cdot \rho_e^o = 4.54x10^{17} kg/m^3$, ($\rho_e^0 = 22.24\ x10^{13}\ kg/m^3$), in the CGT's model, the density of the $\boldsymbol{\Gamma_\mu}$ -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 $\boldsymbol{\Gamma_\mu}$ -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: $\rho_n(r) = \rho_n^0(0).e^{-r/\eta'}$ with η' = 0.87 fm, (equal to the proton's root-mean square charge radius, experimentally determined: 0.84 ÷0.87).

Eq. (1) gives- with $\upsilon_i(a_i) = 0.9\ fm^3$, a value $V_n^0 = 115\ MeV$ and: $V_n(d=2fm) \approx 9MeV$ – value specific to the mean binding energy per nucleon in the nuclei with the most strongly bound nucleons, (9.14 ÷9.15 MeV/nucleon for ^{56}Fe, ^{58}Fe, ^{60}Ni, ^{62}Ni).

The resulting maximal density ρ_n^o 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 Eq. (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 is 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 ($m_f \approx (10^{-40} \div 10^{-41})$ 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: $P_s(a_i) + P_d(a_i) = P_s^0(a_i)$ = constant.

Similarly, the strong force between quarks is explained in CGT by a 'bag' model [18] resulting from the obtained (multi)vortical model of nucleon by taking $\upsilon_i(r_q) \approx (0.0335 \div 0.0388)\ fm^3$, ($r_q \approx$ (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 $z^0 = 42\ m_e^* \cong 34\ m_e$ 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: $z_2(4z^0) = 136\ m_e$ and: $z_\pi(7z^0) = 238\ m_e$.

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 > 1MeV. For example, the gamma quantum resulted in the transforming reaction: $\pi^0 \rightarrow 2\gamma$ represent a $z_2(136\ m_e)$ –boson, and the gamma quantum emitted in the nuclear reaction: $^7Li + p \rightarrow 2\alpha + \gamma(17.2\ MeV)$, (used by Cockcroft and Walton in 1932 [18]) for verify the formula: $E = mc^2$ and founding 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(17.37MeV).

It was also considered in astrophysics a theoretic (hypothetical) model of exotic star formed as network of quarks, named 'quark star', formed at extreme temperature and pressure, inside a neutron star, [19], 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. 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 [20], 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, [21].

It was also concluded [22] that the transition from neutron matter to quark matter begin at densities around $(1.5 \div 4)x10^{18}$ kg/m^3.

However, it was recognized that the transition point between neutron-degenerate matter and quark matter and the equation of state of quark matter are uncertain, [23].

It is also known that neutron stars, which are extremely hot when they are formed, cool down thereafter through processes including thermal radiation, neutrino emission, and the formation of a solid crust.

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 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, ('kerneloids' –in CGT, [17]).

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 is considered that the electron's mass is formed by a 'kerneloid' containing the (super)dense kernel m_0 of radius $r_0 \leq 10^{-18}$ m and by a shell of bosons which in the electron's case are 'naked' photons, in concordance with the evidenced possibility to obtain a B-E condensate of photons [24] .

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 to some high-energy scattering experiments reported by Milonni et al. (1994, p.403 [25]).

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: $r_z \approx 3.5\times10^{-2}$ fm, if it would be spherical, (in "melted" drop form), by an empiric equation which –for a current u/d-quark considered as spherical, gives a radius: $r_q \approx 0.21$ fm- specific to an inflated quark [11] with volume: $\upsilon_{qi} \approx 3.87\times10^{-2}\mathrm{fm}^3$ and concordant with older experiments [26; 27]:

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

in which υ_{ni}(0.6fm) is the volume of the nucleon's 'bag' containing rotated and vibrated current u/d-quarks (at ordinary temperature $T_n \approx 1\mathrm{MeV}/k_B$) 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.

Eq. (2), for $m_k = m_z^0 = 34\ m_e$, gives: $\upsilon_{zi} \approx 1.78\times10^{-4}\ \mathrm{fm}^3$, $r_{zi} \approx 3.5\times10^{-17}$ m.

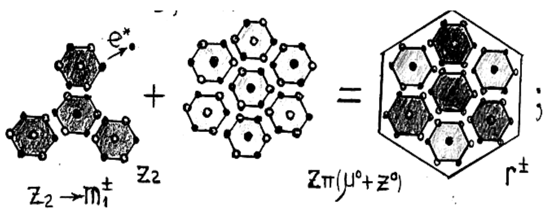
For a z^0-preon with $n_z = 42$ quasi-electrons, the electron's kerneloid radius r_{ie} results approximately by: $r_z \approx r_{ie}\cdot n_z^{1/3}$, of value: $r_{ie} = r_{ie}^0 = 0.01$fm –which is the value reported by Milloni [25]. So, in consequence, we will use this value: r_{ie}^0 for recalculate 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 –conform to CGT's model, 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^e_μ -vortices of the degenerate magnetic moments, maintained by their kernels, in accordance with a classic equation of electron's intrinsic rest energy [10]:

$$m_e c^2 \approx \tfrac{1}{2}\int \varepsilon_0 E^2 dV(r) \approx \tfrac{1}{2}\int \mu_0 H^2 dV(r); \qquad (E = c\cdot B;\quad r = 0 \div r_\mu = \hbar/m_e c) \qquad (3)$$

which explains the electron's mass m_e as saturation value: $n\cdot m_f$ of magnetically (vortically) confined 'naked' photons. These Γ_μ^e -vortices are maintained by the negentropy of the quantum vacuum given by etherono-quantonic winds (fluxes), which explains also the constancy of the magnetic moment of the free charged particles, in CGT [10].

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



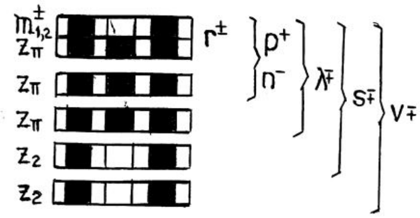
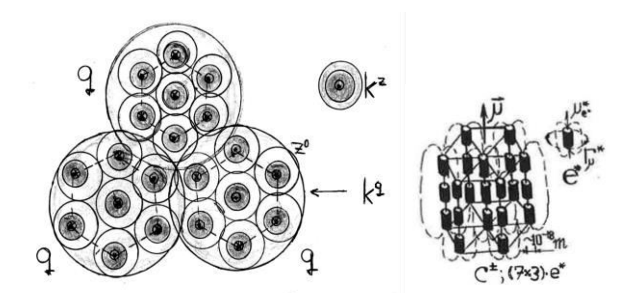


Fig. 1, *the m_1^*, z_π^* and r^*- quark pre-clusters forming from z^0-preons.*

Fig. 2, *the cold forming of semi-light quarks by pre-clusters of $m_{1,2}$; z_2 and z_π*

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, (fig. 1, 2), the quarks confining force resulting in CGT by magneto-electric interaction between quasielectrons and by a 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 $r_i^* = a_i \approx 0.6$ fm [16], (as in the "bag" model of Toki & Hosaka).



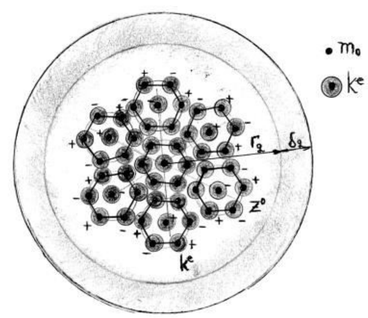


Fig. 3, *Baryonic and preonic kerneloid,* [11] **Fig. 4,** *Preonic z_π-layer of quarcic kerneloid,* [17]

Fig. 5, *The cold forming of semi-light quarks, (3D)*

From figure 4 representing a preonic z_π -layer of a quarcic kerneloid it results that the radius value: $r_{ie}^0 \approx 10^{-2}$ fm [25] of the quasielectron's kerneloid, ensures a mean distance:
$d_i \approx (^2/_3)\cdot r_z = 2\text{x}10^{-2}$ fm between the electronic centroids m_0 on the radial direction at T = 0K, which gives a value: $r_{iz} = 3\ \text{x}10^{-2}$ 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: $l_z = 6\text{x}d_i \approx 0.12$ fm.

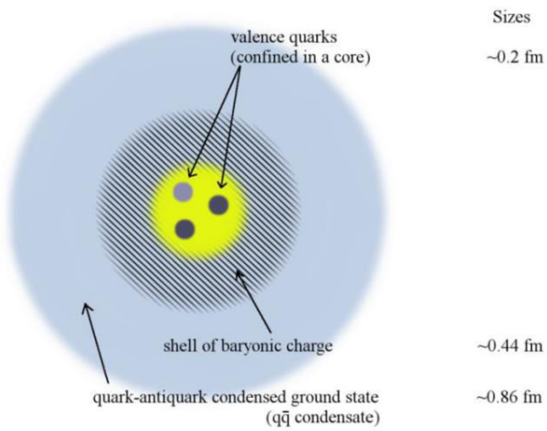


Fig.6. *The proton as a Condensate Chiral Bag, [26]*

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

The minimal radius of the quark's kerneloid (specific to its ultra-cold state, T = 0K) results of value: $r_q^0 \approx 3xr_z = 0.09$ fm - which gives a current quark's volume: $\upsilon_q^0 = \pi r_q^2 l_q = 0.91x10^{-47} m^3$.

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 = 0K.

In report to these theoretic values, of T = 0K, the value: $r_q^i \approx r_i/2 = (0.21 \div 0.23)$ fm used in the CGT's model as radius of a spherical current u/d-quark in concordance with older experiments [26; 27] represents a radius of dilated volume of current (u/d)-quark: $\upsilon_q^n \approx (3.35 \div 3.38)x10^{-47}$ m^3, that corresponds to a small vibration liberty l_v^z of the z^0-preos inside the quark's kerneloid, giving its repulsive shell, of thickness $\delta_q(l_v^z) \approx (0.01 \div 0.03)$ fm [16], of a scalar repulsive charge, q_s, and an interaction radius: $r_q^i = r_q + \delta_q$, ($r_q = 0.2$ fm).

The inflated quarcic volume υ_q^n corresponds to vibrated z^0-preons, i.e. to apparently dilated kerneloids of internal z^0-preons, whose apparent volume results of value: $\upsilon_k^z \approx \upsilon_q^n/18 =$ $=1.86x10^{-48}$ m^3, i.e. of apparent radius: $r_k^z \approx 3r_k^e \approx 7.6x10^{-2}$ fm, for a volume approximated as spherical, (compared to $3.5x10^{-2}$ fm- for a compact z^0-cluster of quasielectrons at 0K).

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

By the value of the nucleon's kernel maximal density obtained in CGT as apparent value, ($4.54x10^{17}$ kg/m^3), the current quark's radius $r_q \approx 0.2$ fm corresponds to a mass of nucleonic quark: $m_n \geq 8.55$ MeV/c^2, which reduces the mass and the mean density of quasi-free photons inside the nucleon's "impenetrable" quantum volume, $\upsilon_i(r_i)$, ($r_i = (0.44 \div 0.6)$ fm, [26], Fig. 6).

The mechanical radius r_i^n of the nucleon's impenetrable volume υ_i is given in CGT by a compact cluster of three un-vibrated quarcic kerneloids (fig. 3) and it results of value: $r_i^n \approx 2r_q^i = 2(r_q + \delta_q) \approx 0.44 \div 0.46$ fm– in good accordance with the experiments of electrons scattering to nucleons, (~0.44 fm [26] –radius of $\upsilon_i(r_i)$,), while the value $r_i = r_i^f \approx 0.6$ fm represents in CGT the nucleon's kernel of interactions by nuclear field and the 'bag's radius of the "bag" model of strong interaction [16] , (used and by the Toki & Hosaka's bag model), given as real 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.

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 $r_f \leq 10^{-2}$ fm, for $m_f < m_e$ and having a Γ_μ^f-vortex sustained by a superdense centroid of radius $r_0^f \leq r_0 = 0.43 \times 10^{-3}$ 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 ($r_{ie} \geq 10^{-2}$ fm), given by a dense shell of photons, corresponding to the mean density level, ($\rho_i^e \leq \rho_q^0 = m_q^n/\upsilon_q^0 = 7.5\text{MeV}/c^2 \cdot 0.91 \times 10^{-47} = 1.46 \times 10^{18}$ kg/m^3) and:
- the electron's classic radius ($a_e \approx 1.41$ fm), corresponding to the low density level, ($\rho_a \approx 5.16 \times 10^{13}$ kg/m^3), and to a quasi-superficial distribution of the electron's e-charge.

2.2.. The structure of the heavy quarks in CGT

In CGT, the fractional charge of quarks is formal, the particle's charge being given by electron(s) with 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 ($\approx m_s^* = 987.8\ m_e$, ~0.504GeV/c^2) -the mass of s-quark;
b) $m_c = 1.7$ GeV/c^2 = 3326.8 m_e –charm quark's mass used by de Souza [28], and:
c) $m_b \approx 5$ GeV –bottom quark's mass used by de Souza [28],
d) $m_t \approx 175$ GeV, the t-quark resulting as collapsed cluster: $t^{\pm} = (7\text{x}5)m(b^{\pm})$; $(17(b\bar{b}) + b^{\pm})$.

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

$$m_n^{\wedge}(q_n) \approx m_1 \text{x} 3^{n-1} \;;\quad q_n = [(q\bar{q})q]_{n-1} \tag{4}$$

obtained by Karrigan Jr., [29] for quarks of S.M., (for masses: $m_n^{\wedge} = m_2^{\bullet} = m_c^{\bullet} = 1.55$ GeV/c^2 and $m_3^{\bullet} = m^{\bullet}_b = 4.73$ GeV/c^2 , with: $m_1^{\bullet}(q_1) = m_s^{\bullet} \approx 0.486$GeV/c^2), but in a modified form:

$$m_n(q_n^c) = 3^{n-1}[m_1 - (z^0/3)(2n-3)];\ n > 1, \quad (\text{or: } m(q_n^c) = 3^{n-1}[m_1 - (z^0/3)\ln(3^{n-1}3^{n-2})]); \tag{5}$$

by taking : $m_1 = m_v^* \approx 1121.2\ m_e \approx 0.574$ 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: $m_4^* = m(c^*) = 3m_v^*(v^+) = 3363.6\ m_e$, (1.718 GeV/c^2), and respective: $m_5^* = m(b^{*\pm}) = 3m_c \approx 5.1$ GeV/c^2, (q^* -'cold' quark), by the next de-excitation reaction specific to Eq. (5):

$$c^{*\pm}[(v^{\pm}\bar{v}^{\pm})\,v^{\pm}] \rightarrow c^{\pm}(\sim 1.702\text{GeV}/c^2) + z^0(34m_e) \tag{6a}$$

$$b^{*\pm}[(c^{\pm}\overline{c}^{\pm})\, c^{\pm}] \;\rightarrow\; b^{\pm}(\sim 5\mathrm{GeV}/c^2) + z_3\,(204\, m_e)\,; \qquad z_3 = z_{\mu} = (2x3)z^0 = 2z_1 \qquad (6b)$$

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

$$c(1700)\rightarrow c^{\bullet}(1561) + \pi^0(2z_2);\;\; b(5000)\rightarrow b^{\bullet}(4756) + z_6(2z_{\pi});\;\; s^{\pm}(500)\rightarrow s^{\bullet\pm}(483) + z^0. \quad (7)$$

i.e. by an equation of the form:

$$m(q_n^{\bullet}) = 3^{n-1}[(m_1 - \delta) + (z^0/3)(n-2)] \approx 3^{n-1}[(m_1 - \delta) + (z^0/3)\ln 3^{n-2}], \qquad (8)$$

$$[(m_1 - \delta) = (2m_s + m_v - z^0)/3]$$

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

The Gell-Mann / Okubo mass formula which relates the masses of members of the baryon octet, [30-32], used by Gell-Mann for predict the mass of the Ω^- baryon in 1962, which is given by:

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

is verified in CGT by observing that the known masses give: $2(m_N + m_{\Xi}) + z^0(17) = 3m_{\Lambda} + m_{\Sigma}$ and that it results the next structure specific to CGT:

$$2[(2n + p) + (2s + p)] + z^0 = 3(s^{\bullet} + n + p) + (v + n + p); \quad (s^{\bullet} = s - z^0) \qquad (9b)$$

Eq. (9b) being verified by the next weak reactions: $3s \rightarrow 3s^{\bullet} + 3z^0$; $s^- + 4z^0 = s + z_2 = v^-$.

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's mass obtained in the S.M.

The resulting structure of quarks in CGT is based to the conclusion that in scattering experiments, the value of the determined radius is inverse 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:_ $r_0 \leq 10^{-18}$ m corresponds to a 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: $r_q^n \approx 0.2$ fm, initially deduced for the nucleonic current quark [26; 27], 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, [26; 33].

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, $m_q(r_q^n)$), it results a transition limit ρ_l corresponding to $r = r_q^n$, (i.e: $\rho_q(r_q^n) = \rho_l$).

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 the current quark, increasing its mass m_q^i with a quantity $\delta m_q = n \cdot m_z$, because the increasing of also its total vortical field V_Γ, given by its degenerate electrons, (Eq. (1)), then 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 $m_q^c > (m_q^i + n \cdot m_z)$.

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 :
$m_d^c \leq 8.5$ MeV/c^2, this maximal possible value of CGT being close to that obtained by S. Weinberg [34] for the mass of the current d -quark : $m_d \approx 7.5$ MeV/c^2, [34], (instead of ~ 5.2÷5.5 MeV/c^2 –currently considered by the Standard Model –value calculated by the chiral quark model [35]).

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 [36], it was calculated that [34]:

$$m(u): m(d): m(s^\bullet) = 1:1.8:36 \qquad (10)$$

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:

$m_s^\bullet = 150$ MeV; $m_d = 7.5$ MeV; $m_u = 4.2$ MeV.

Also, it was calculated that:

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

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

$$m(\tau): m(\mu): m(e) = 3600:200:1 \qquad (12)$$

The constituent quark masses M_q of the naïve quark model include spontaneous effects which give [34]:

$$M_q^{\bullet} = m_q^{\bullet} + \Delta_q(350\text{MeV}/c^2) \qquad (13)$$

the value $\Delta_q = 350\text{MeV}/c^2$ representing the mass of gluonic shell of the current quark and being deduced from the mass of nucleon's constituent u-quark, considering the current mass of u; d-quarks very small compared to its effective mass.

- If we choose: m(u): m(d) ≈ 2.9 MeV: 5.5 MeV, (values currently agreed by S.M. [1]) , it results by Eq. (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 Eq.(13) with: $m_s^{\bullet} = 110$ MeV:

$$\Delta_q = M_s - m_s = 376\ [\text{MeV}/c^2]\ ; \qquad (14)$$

$$M_q^n = m_q^n + \Delta_q(350 + 26)\quad [\text{MeV}/c^2] \qquad (15)$$

with: $M_q^1 = M_s^{\bullet}$; $M_q^2 = M_c^{\bullet}$; $M_q^3 = M_b^{\bullet}$, resulting that: $m_c^{\bullet} = 1174\ \text{MeV}/c^2$; $m_b^{\bullet} = 4354\ \text{MeV}/c^2$, (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 a 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 see if Eqs. (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 quarks kerneloid and the bosonic equivalent of gluons are 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 ($u\,\bar{u}$) –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 [20] can 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 $<\ \bar{\psi}_i(x)\ +\psi_j(x)>$ generated by a spontaneous symmetry breaking which imply 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).

Because a similar mechanism can occur also 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 the previous explanation of the faster growth of the quark's current mass than that of its constituent mass, (Eq.(15)).

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

Eq. (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): $M_c' \approx 1700$ MeV/c^2, b(bark): $M_c' \approx 5000$ 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, conform to Eqs. (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 proportional 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 supposes 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 (Eq. (1), which increases proportional to the number of z^0-preons, i.e. proportional to the quark's mass:

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

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

Eq. (16) (specific to CGT) can explain Eq. (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 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/c^2; $M_d \approx 313.5$ MeV/c^2 , [9-11], (values which give the nucleon's mass by the sum rule) and $m_d \leq 8.5$ MeV, then the current d-quark's mass: $m_d = (5.5; 7.5)$ MeV/c^2 correspond to the differences: $\Delta_d = M_d - m_d = (306\div308)$ MeV/c^2, respective: $\Delta_{s\bullet} = (350 \div376)$ MeV/c^2, obtained by Eqs. (13), (15), which indicates an increasing of Δ_q with m_q, ($\Delta_s \neq \Delta_d$), 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 [36]), can result as ansatz, in the form:

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

with $M_{s\bullet} = M_s^\bullet(486\text{MeV})$ – the constituent mass of $s^\bullet$ –quark. The constants A_q, k_q, must be obtained by taking: $m_d = 7.5$ MeV/c^2, (Ref. [34]), or $m_d^\bullet \approx 5.2\div5.5$ MeV/c^2, (currently accepted).

For $m_d = 7.5$ MeV/c^2 and the ratio: $m_s/m_d \approx 20$, (Eq. (10)) $\rightarrow m_s^\bullet \approx 150$ MeV/c^2 , Ref. [34]), with: $\Delta_d = (M_d - m_d)_{CGT} = (313 - 7.5) = 305.5$ MeV/c^2 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.:
$M_q = (M_d; M_s^\bullet; M_c^\bullet; M_b^\bullet)_{CGT/SM} = (313; 486; 1557; 4730)$ MeV/c^2, it results:
$A_q = 336$ MeV/c^2, $k_q \approx 0.0674$, and:
$\Delta_d = 305.5$ MeV/c^2; $\Delta_{s\bullet} = 336$ MeV/c^2; $\Delta_{c\bullet} = 357$ MeV/c^2; $\Delta_{b\bullet} = 359.2$ MeV/c^2, and:
$m_d = 7.5$ MeV/c^2; $m_s^\bullet = 150$ MeV/c^2; $m_c^\bullet = 1193$ MeV/c^2; $m_b^\bullet = 4370$ MeV/c^2,

these values being relative close to those given by Eq. (11), obtained in Ref. [34] by $m_d = 7.5$ MeV/c^2: (150; 1200; 4400) MeV/c^2, (and less to those specific to S.M.).

We observe- in consequence, that Eq. (17), which considers a low increasing of Δ_q with M_q , gives m_q –values closed to those obtained in the S.M. being in same-time more natural than Eq. (15) specific to S.M., (at least for the CGT's quark model).

For $m_d \approx 5.5$ MeV/c^2, by $m_s^\bullet \approx 110$ MeV/c^2 given by Eq. (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 Eq. (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, and:
$m_{d\bullet} = 5.5$ 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 relative close to those specific to the S.M.: (5.2; 104; 1275; 4210) MeV/c^2, (with higher difference at $m_{c\bullet}$, as in case of the using of Eq. (15)).

3.2. The compatibility with CGT of the values (5.5; 7.5) MeV/c^2 of the d-quark's current mass

The value m_d = *7.5 MeV/c^2* of the current d-quark [34], (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 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: $\rho_e(r) = \rho_e^0 \cdot e^{-r/\eta^*}$, ($\rho_e^0$ = 2.224x10^{14} kg/m^3), then we can approximate the proton's density variation by the sum rule, as: $\rho_n(r) = \rho_n^0(0).e^{-r/\eta^*}$ 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 [37]), the proton's mass ($m_p \approx$ 1.67x10^{-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 [27]), 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 = 1.56x10^{-10} [m^2/C]), conform to the next relation:

$$M_p = 4\pi \cdot fN^p \rho_e^0 \int_0^a r^2 e^{-\frac{r}{\eta^*}} = 4\pi\rho_n^0 \cdot (\eta^*)^3 \left\{ 2 - \left[\left(\frac{r}{\eta^*} \right)^2 + 2\frac{r}{\eta^*} + 2 \right] e^{-\frac{r}{\eta^*}} \right\} \quad (r = a = 1.41\ \text{fm}) \quad [\text{kg}]; \qquad (18)$$

the value of the maximal density: ρ_n^0 = 4.54x10^{17} kg/m^3 being 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. [34]), 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:

$$\Delta\upsilon_i = (\upsilon_i(r_i) - 3\upsilon_q) \Rightarrow \Delta m_i \approx \rho^* \cdot \Delta\upsilon_i = (m_i(r_i) - 3m_q); \quad (\rho^* = \rho_i(r^*) \approx \rho_n(r^*);\ \upsilon_q = \upsilon_q(r_q)) \qquad (19)$$

It can be verified, by calculating the m_i –mass with Eq. (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 [26]), corresponding to a quarks' arrangement conform to Fig. 3. This r_i –value gives for υ_i a mean density: $\rho_i(r_i) \approx$ (2.7÷2.77)x10^{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: $\rho_d \approx$ 4x10^{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, (Eq. (16)), while the density of a d-quark with m_q = 5.5 MeV/c^2, (ρ(5.5) $\approx$ 2.93x10^{17} kg/m^3 = ρ_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} kgxm^{-3}, (S. N. Shore, [22]), this value being a little higher than the nuclear saturation density: $\rho_n^s \simeq 2.6\times10^{14}$gxcm^{-3} .

Using in Eq. (19) the value: $r^\bullet = 0.44$ fm- experimentally determined [26], with Eq. (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 Eq. (18), it results the next values:
$m_i(r^\bullet) = 0.111194\text{x}10^{-27}$ kg; $\Delta\upsilon_i = (\upsilon_i(r^\bullet) - 3\upsilon_q) = 0.25664\text{x}10^{-45}$ fm^3; $\rho_n(r^\bullet) \approx 2.74\text{x}10^{17}$ kg/m^3; and with $\rho^* \approx \rho_n(r^\bullet)$, it results: $\Delta m_i = \rho^*\Delta\upsilon_i \approx 0.0703\text{x}10^{-27}$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:

$\rho_i(r) = \rho_i^0\cdot e^{-r/\eta i}$, $(\rho_i^0 = \rho_s = 2.93\text{x}10^{17}$ kg/m$_3$); $\rho_m = \rho_s(\eta_i/r^*)\int e^{-r/\eta i}dr$, $(0 \le r \le r^*)$,

which – by $\rho_i(r^*) = \rho_n(r^\bullet)$, gives: $\eta_i = 5.5$ fm; $\rho_m \approx 2.8\text{x}10^{17}$ kg/m^3 and $m_q \approx 7.4$ MeV/c^2 .

The value $r_i = r^* \approx 0.43\div0.45$ fm corresponds to a vibration liberty of small amplitude of current quarks inside the nucleon's impenetrable volume, and in this case, the value: $m_d^* = (7.5 \div 7.8)$ 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 2.62 m_e lower than M_d) corresponds to an almost maximal compactness at nuclear temperature $T_i \approx 1$MeV/k_B , specific to a mechanical interaction between two nucleons, (the value value $r_i \approx 0.59\div0.6$ fm corresponding to a real amplitude of current quarks' vibration inside the nucleon's impenetrable volume).

Also, the quark's radius $r_q = 0.2$ fm corresponds to a dilated quark, with intrinsic vibrations.

Conform to Eq. (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:

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

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, (Eq. (1)), because the vortical field generated by two z^0 – preons diametrically opposed in 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 Eqs. (18), (20), using a proton's scalar radius: a = 1.41 fm, (conform to Eq.: $e = 4\pi a^2/k_1$), 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 S.M.), the proton's scalar radius being the largest, [38].

For $r^* \approx 0.39$ fm , corresponding to $\rho_n(r^*) = 2.9x10^{17}$ 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 Fig. 3, (minimal radius of the quarks' cluster: $r^* = 2r_q \approx 0.4$ fm), so –to a compact cluster of quarks, as in case of a cold nucleon.

Because in CGT it results that $\rho_n(r^* = 0.39$ fm) is very close to: ρ_q'(5.5MeV) = 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 = 7.5MeV results as more plausible than the value: m_d = 5.5MeV.

3.3. The calculation of the current quarks' masses in CGT.

Another argument which indicates that the value m_d = (7.3 ÷ 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 [34] between light current quarks masses m_q and the mesons' masses, M_π , M_K :

$$M_\pi^2 = -(2/f_\pi)^2 (< \bar{d}\cdot d>_0 m_u + < \bar{d}\cdot d>_0 m_d) \approx B(m_u + m_d); \quad B = -(2/f_\pi)^2 < \bar{\psi}\cdot\psi> \qquad (21)$$

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, and $< \bar{\psi}\cdot\psi>$ -the chiral condensate, and by the approximation: $< \bar{u}\cdot u>_0 = < \bar{d}\cdot d>_0 = < \bar{s}\cdot s>_0 = < \bar{q}\cdot q>_0$, (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 Eq. (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 includes mesonic quarks ("mark" –$m_{1,2}$), of mass
M_m = 69.5 MeV/c^2, 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 Eq. (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/c^2 if $m_d = m_d^\bullet$ = 5.5 MeV/c^2 ($^\bullet$ -corresponding to the S.M.) and $m_m \approx$ 1.(6) MeV/c^2 if m_d = 7.5 MeV/c^2, (conform to CGT's conclusion).
Also, the ratio: m_d/m_u = 1.8 (Eq.(10)) is specific to a mass difference: δm = 5.2 – 2.9 = 2.3 MeV/c^2 = 4.5 m_e –which is higher than the mass difference between the masses of the neutron and the proton (~2.6 m_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:

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

So, considering (for conformity with the S.M.) that $m_m^-/m_m^+ \approx 1.8$, it results that for : $m_m^+ \approx (1.(2)^\bullet\ ; 1.(6))$ MeV/c^2 we have $m_m^- \approx (1.(2)^\bullet; 1.(6))$x1.8 = $(2.2^\bullet; 3)$ MeV/c^2.

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/c^2 ; M_λ = 435.3 MeV/c^2), by Eq. (21) it results- with the theoretic M_p - masses obtained in CGT [10, 17], that:

$$(M_K^0/M_\pi)_t^2 = (989.6/275.6)^2 = (m_m^- + m_\lambda)/2m_m^- = 12.9; \Rightarrow m_\lambda/m_m^- = 24.8 \qquad (22b)$$

while with the experimentally obtained values it results: $(M_K^0/M_\pi)_e^2 = 13.5$; $m_\lambda/m_m^- = 26$.

So, with $m_m^\pm \approx (2.2^\bullet; 3)$ MeV/c^2 we would have: $m_\lambda = (54.5_t; 57.2_e)^\bullet; (74.4_t; 78_e)$ MeV/c^2. However, for $M_s(s^\bullet)$ = 486 MeV/c^2, we can also use the CGT's model [17], resulting that:

$$(M_\eta^0/M_\pi)_t^2 = (1091.6/275.6)^2 = (m_s^\bullet + m_m^-)/2m_m^- = 15.688; \Rightarrow m_s^\bullet/m_m^- = 30.37 \qquad (23a)$$

(M_p given by CGT, in m_e), so with $m_m^- \approx (2.2^\bullet; 3)$ MeV/c^2 we have: $m_s^\bullet = (66.8^\bullet; 91.1)_t$ MeV/c^2.

With the experimentally obtained value of M_η^0 (1073 MeV/c^2), it results: $(M_\eta^0/M_\pi)_e^2 = 16.5$; $m_s^\bullet/m_m^- = 32$, values which by $m_m^- \approx (2.2^\bullet; 3)$ MeV/c^2, give: $m_s^\bullet = (70.4^\bullet; 96)_e$ MeV/c^2.

We observe that by CGT and Eq. (21) the obtained value of $m_s^\bullet$ which is correspondent with the inferior limit agreed by the S.M., (92 MeV/c^2) is the value: $m_s^\bullet$ = 91.1 MeV/c^2, obtained by: m_d = 7.5 MeV/c^2, which gives: $m_m^+ \approx 1.(6)$ MeV/c^2, (corresponding to $M_{m+} \approx 69.1$ MeV/c^2) and $m_m^- \approx 3$ MeV/c^2, (corresponding to $M_{m-} \approx 70.4$ MeV/c^2 and to: $\Delta_{s\bullet} = M_s^\bullet - m_s^\bullet$ = 395 MeV/c^2).

Also, for $M_s(s)$ = 504 MeV/c^2 [10], (i.e. non-de-excited s –quark of CGT [17]), it results that:

$$(M_\eta^0/M_\pi)_t^2 = (1125.6/275.6)^2 = (m_s + m_m^-)/2m_m^- = 16.68; \Rightarrow m_s/m_m^- = 32.36 \qquad (23b)$$

(M_p in m_e), so with $m_m^- \approx 3$ MeV/c^2 we have: m_s = 97.1 MeV/c^2 and $\Delta_s = M_s - m_s$ = 407 MeV/c^2.

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 $\eta^0(1073\ m_e)_e$ and $K^0(974.5\ m_e)_e$ by the GMOR relation and the Gell-Mann-Okubo relation, but written in the form :

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

By Eq. (17), recalculating the values A_q and k_q by the conditions: $\Delta_{s\bullet}$ = 395 MeV/c^2 and: Δ_d = (313 -7.5) = 305.5 MeV/c^2, we obtain: A_q = *395* MeV/c^2 ; k_q = *0.182*, which give: Δ_s = 400 MeV/c^2 ; m_s' = 104 MeV/c^2, that compared to: m_s = 97.1 MeV/c^2 (by Eq. (23b)) give a difference of 7%, which indicates that Eq. (17) and the obtained values for A_q, k_q , are satisfactory.

For the quarks $c^\bullet$ and $b^\bullet$, and: c and b, by Eq. (17), for m_d = 7.5 MeV/c^2 we obtain: $\Delta_{c\bullet}$ = 465.4 MeV/c^2 , $m_{c\bullet}'$ = 1091 MeV/c^2 , and: $\Delta_{b\bullet}$ = 473 MeV/c^2 , $m_{b\bullet}'$ = 4257 MeV/c^2.

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/c^2 , Eq. (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 Eq. (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 the minimal values of the current quark's volume, in CGT.

Conform to Eqs. (15), (16), (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 baryions and other multi-quark particles.

The volume 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 sum of preonic kerneloids, with their volume considered as in the nucleon's case, i.e. with the radius r_k^z of the apparent volume υ_z^a of the z^0-preons (dilated by vibrations of quasielectrons' kerneloids) approximated by a relation similar to that specific to the nuclear volume:

$$r_i^n \approx r_k^{z} \cdot N_z^{1/3} ; \qquad (24)$$

usable by considering the volume of quark's kerneloid as being approximately quasi-spherical, and extrapolating the case of the nucleon's impenetrable volume $\upsilon_n(r_i^n)$ at nucleon's temperature: $T_n \approx 1$MeV/k_B to the case of a composite current quark (tri-quark) at ordinary temperature T_n .

With: r_i^n = 0.44 fm [26]; $N_z \approx 1836m_e/34m_e = 54$, (for proton), it results that:

r_k^z = 0.12 fm, (υ_z^a = 0.723x10^{-47} m^3), the kerneloid of a protonic quark (u; d) having -by Eq. (24), at ordinary temperature $T_n \approx 1$MeV/k_B, an apparent radius: r_k^n = 0.12x$18^{1/3}$ = 0.31 fm,.

The apparent value: r_k^z = 0.12 fm, being equal to the length of a cold z^0-preon, correspond to a prismatic z^0-preon dilated more radially than axially.

Conform to Eq. (24) and the mentioned extrapolation, the minimal radius of the s-quark considered in the Standard Model's' variant (flavor), ($M_s \approx 486$ MeV/c^2; $N_z = 28$), results of value: r_k^s = 0.12x3.04 = 0.365 fm, corresponding to a maximal density of the current s-quark with mass calculated by $m_d(5.5)$: ρ_k^s = 0.96x10^{18} kg/m^3.

For the CGT's variants of quarks it results the next values of r_k^q :

-The minimal radius of the s-quark considered in the Souza/CGT' variant (flavor), ($M_q \approx 0.5$ GeV/c^2 ; $N_z = 29$), results of value: r_k^s = 0.12x3.07 = 0.37 fm.

-The minimal radius of v-quark of CGT, (~0.574 GeV/c^2; $N_z = 33$), results of value:

r_k^v = 0.12x3.21 = 0.385 fm; (corresponding –by the arrangement specific to Fig. 2, to a prismatic v-quark dilated more radially than axially, as consequence of stronger magnetic force between quasielectrons on axial direction, conform to CGT).

-The minimal radius of 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 = 0.12x4.61 = 0.55 fm, and corresponds to a quarks cluster dilated more radially than axially; (the high of c-quark in the arrangement specific to Fig. 3 with the real value: $r_z \approx 3x10^{-2}$ fm resulting of value: $h_k^c \approx h_k^v = 6l_z$ = 0.72 fm,).

- The minimal radius of a 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 Eq. (24) of value: r_k^b = 0.12x6.6 = 0.79 fm, in CGT; (with the same arrangement of Fig. 3, but as formed by c-quarks, corresponding to a quarks cluster dilated more radially than axially).

3. *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, [39] .

Also, it was concluded [39] that when the strange chemical potential μ_s crosses the charm quark threshold, the following weak equilibrium reaction is allowed to take place:

$$u + d \leftrightarrow c + d; \tag{25}$$

yielding the condition: $\mu_c = \mu_u$, the electric charge neutrality condition being satisfied by the participation of free muons, which appear when $\mu_\mu > m_\mu c^2$ =105.7MeV 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 as cluster of three strange quarks [17], a cold charm star could be stable at very low temperatures T→0K 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 = 300K of the particles' environment, and considering its dependence to 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:

$$\tau_k = \frac{\tau^0}{k_v \cdot 10^{2n}} \approx \frac{\tau_0 \cdot m_p}{\Delta m_p(T)}; \quad \tau^0 \cong 3x\,10^{--14}\,\text{sec.}; \quad k_v = \frac{\varepsilon_v}{\varepsilon_v^o} = \frac{n \cdot \nu_i}{\nu_c^o} = \frac{n \cdot T}{T_N}; \quad T_N \cong 2x10^{12}\,K \tag{26}$$

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 take place: $\nu_c^0 = \nu_c(T_N \approx 2x10^{12}K) \approx 4x10^{22}$ Hz.

Equation (26) may explain the fact that the heavy baryons with composite heavy quarks can have a longer lifetime at T→0K (temperature that is not reached due to zeroth vibrations) but cannot have a long life at an ordinary temperature.

For the d- quark with current mass $m_d' = 7.5$ MeV/c^2, the corresponding density: $\rho_d = 4x10^{17}$ kg/m^3 obtained in CGT 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 crust up to (6÷ 8)$\times10^{17}$ kg/m^3 in 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, for a stellar mass $M_S < 1.5M_\odot$ [40], ($M_\odot$ -solar mass).

Conform to CGT's model of quark [12; 13], the previous observations are explained by the conclusion that- inside the central part of a neutron star, the neutrons are reduced to their kerneloids formed by current u/d-quarks which have a behavior of composite particles, the necessary of a higher gravitation force for the transforming into quark star with higher density being given by the current quarks' fusion at higher temperature and by the photonic pressure of the kerneloids' pseudo-charge q_s given by their 'bag' constant B.

This indicates logically a compactness of the neutrons matter corresponding to Eq. (24) and a possible increasing of the d-quark's mass and density, specific to the quark star's forming, which imply the transforming of some nucleonic quarks into heavier quarks.

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

$$N_e(2d + u) \to \bar{s}^- + \lambda^- \quad ; (d^- + u^+ \to \bar{j} \to \bar{s}^- + z_\pi ; \quad d^- + z_\pi \to \lambda^-) \qquad (27a)$$

which shows that a neutron can be transformed- even at T →0K, 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, ($\bar{j}$- 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, conform to CGT, giving a quark's repulsive scalar pseudo-charge, q_s [16]).

The reaction (27a) can result also 'at cold', at T→0K –conform CGT, because 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 also the variant:

$$N_e(2d + u) \to \lambda^- + \bar{s} ; \; (d^- + u^+ \to \bar{j} \to \lambda^+ + r^- ; \quad d^- + r^- \to \bar{s}^+) \qquad (27b)$$

i.e. by the forming of antiquarks $\bar{s}^+$, with a q-charge of (-$^2/_3$)e, but it is less probable.

So, it results conform to Eq. (27), the possibility of a 'mesonic star' forming, because the pair ($\bar{s} + \lambda^-$) corresponds as structure to a meson having almost the same mass as a neutron (M_N = 939 MeV/c^2), the hypothetical 'strange star' resulting in CGT rather a hybrid star, formed by s-antiquarks and lambda-quarks.

In their turn, the resulting mesons (convenient notation: $N_\pi(\lambda^- \bar{s})$) can form couples which are equivalent to neutral tetra-quark particles, (or octo-quark particles) with mass ~1877 MeV/c^2, (respective: 3754 MeV), but as network of current quarks λ^- ; $\bar{s}$. Conform to Eqs. (17); (24), the kerneloid's mass and radius of these particles would be: $m_q(2N_\pi)$ = 1409 MeV; $\upsilon_n(r_q = 0.57$ fm) = 0.775x10^{-45} m^3, (respective: $m_q(8N_\pi)$ = 3281 MeV; $\upsilon_n(r_q = 0.72$ fm) = 1.56x10^{-45} m^3).

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, [41].

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 $T_q < 1MeV/k_B$, because the reducing of 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 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.

- Regarding the current quarks' density, the previous values of r_k^q, obtained by Eq. (24), correspond to the next minimal volumes of current quarks, (in 10^{-45} m^3):

$\upsilon_{u/d} \approx 0.0335$; $\upsilon_s(0.486) \approx 0.2$; $\upsilon_s(0.5) \approx 0.212$; $\upsilon_v(0.574) \approx 0.239$; $\upsilon_c(1.7) \approx 0.696$;
$\upsilon_v(5) \approx 2.064$, ($x10^{-45}$ m^3).

The mean densities of the mentioned current quarks of Souza/CGT's variants, resulting as specific to a compactness corresponding to a cold quark star, have in this case- with:
m_d =7.5MeV and: ($m_s^{\bullet}$ = 91; m_s' = 104 ; m_v' = 158 ; m_c' = 1233 ; m_b' = 4527) MeV/c^2,
the values:

$\rho_k^{s\bullet} = 0.8x10^{18}$; $\rho_k^s = 0.87x10^{18}$; $\rho_k^v = 1.17x10^{18}$; $\rho_k^c = 3.15x10^{18}$; $\rho_k^b = 3.9x10^{18}$ [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 Eq. (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 Eq. (16), the approximate relation: $M_b' \approx 3M_c'$, the difference between the maximal possible densities: ρ_k^c and ρ_k^b is considerable smaller:
$\rho_k^b \approx 1.24\cdot\rho_k^c$, so we can consider the value: $\rho_k^b = 3.9x10^{18}$ kg/m^3 as close to the saturation mean value for the heavy current quarks density.

For the top- quark, (M(t) = 7x5M(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.

The mass difference $\Delta M_t = (M_t - m_t) \approx 2GeV/c^2$, ($m_{tSM} \approx 173$ GeV, compared to: $m_t = 174.5$ GeV/c^2 –given by Eq. (17)) is explained as in 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_bx35 – 2000)/35 = 416 MeV/c^2 per b-quark, which represents $\delta\Delta_q \approx 8.3\%$ of its current mass and to a saturation mean density of value: $\rho_k^t \approx (1+ \delta\Delta_q)\rho_k^b = 4.2x10^{18}$ kg/m^3 .

The obtained values for the mean density of current quarks ($\rho_k^q = (0.8 \div 4.2)x10^{18}$ kg/m^3) can also be specific to the density of some quark stars formed inside a neutron star 'at cold', at $T\to0K$, for which the necessary pressure for its forming is given by the gravitation force and the strong force given by Eq. (1), the compactness of the current quarks' network being conform to Eq. (24), the bosons of the quarks' shell Δ_q (of photons – in CGT) being remained inside the spaces between the volumes υ_k^q of the current quarks m_q .

It is observed that for bigger quarks/particles, ($M_q >> M_s$), 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, Eq. (17) becoming as in the S.M., with Δ_q = constant.

Taking into account also Eq. (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 the density: $\rho_k^q \approx \rho_k^q(2N_\pi) = m_N/\upsilon_{iN} = 1{,}409$ MeV/0.775x10^{-45} m^3 = 3.23x10^{18} kg/m^3, and respective: $\rho_k^q \approx \rho_k^q(4N_\pi) = m_{2N}/\upsilon_{2N} = 3{,}281$ MeV/1.56x10^{-45} m^3 = 3.74x10^{18} kg/m^3.

These values are around the value: $\rho_k \approx 3.45$x10^{18} kg/m^3 obtained as density in the center of the pulsar PSR J1614-2230, [42].

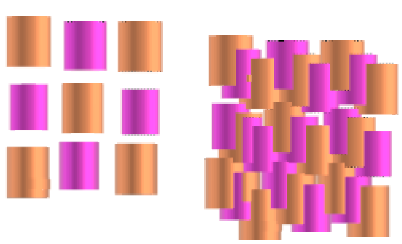
The hypothesis looking the possibility of quark star' forming by quarks with a mass/density comparable to that of a top quark can result by Eq. (27) by the heavy clusters' forming of current quarks λ^+ and $\bar{s}^+$, coupled magnetically and by the strong force in structures of types:

$$S_q^- \approx 4.5N_\pi = [(\lambda^- - \bar{s}^- - \lambda^-) + (\bar{s}^- - \lambda^- - \bar{s}^-) + (\lambda^- - \bar{s}^- - \lambda^-)]^- \qquad (28a)$$

$$S_q^- \approx 4.5N_\pi = [(\bar{s}^- - \lambda^- - \bar{s}^-) + (\lambda^- - \bar{s}^- - \lambda^-) + (\bar{s}^- - \lambda^- - \bar{s}^-)]^+ \qquad (28b)$$

i.e. formed by tri-quark clusters: $C^-(\lambda^- - \bar{s}^- - \lambda^-)$ and $C^+(\bar{s}^- - \lambda^- - \bar{s}^-)$, corresponding to a constituent mass: M(C) = (1374; 1443) MeV/c^2, which can form S_q-layers: $C^+C^-C^+$ and $C^-C^+C^-$ 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 corresponding to a constituent mass: $M(\bar{S}_q) = 4M_n + M_{\lambda;S}$ = (4191; 4260) MeV/c^2 , (Fig. 7a), this composite quark having a structure relative similar to that of a bottom –quarks in the Souza/CGT variant, (with constituent cold mass: 5204 MeV/c^2 and the mass of its de-excited state: ~ 5000 MeV/c^2), and corresponding approximately to Eq. (4).

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



a) b)

Fig.7, *The forming of S_q- and B_q – current quarks as clusters of λ^- and $\bar{s}^-$ current quarks*

So, it results conform to CGT, that also a quark star formed by heavy quarks of mass close to that of a bottom quark but also by quarks of three times heavier, could be a stable star at low temperatures, (T→ 0K).

The density of these current non-de-excited H_q-quarks results by Eqs. (17) and (24) , of value: $\rho_H = m_H/\upsilon_{iH}$ = (12,313MeV/c^2)/5.295x10^{-45}m^3 ≈ 4.13x10^{18} kg/m^3 .

It is understood that bigger clusters D_q ('nuggets') of paired current quarks λ^- *and* $\bar{s}^-$, specific to a relative cold quark star, can be stably formed conform to Eqn.: $D_q = n^3C_q$, (n > 3), but in conditions depending also to the mother star's mass and temperature.

This conclusion could explain the detection of some very heavy particles (of "oh-my-God" type, with mass: ~3.2×10^{20} eV, [43]).

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 $(1.5 \div 4)\text{x}10^{18}$ kg/m^3, [22], and- because this transition implies the forming of a quark network with a compactness specific to Eq. (24), this concordance justifies the calculated minimal values of the current quarks' volumes and the used preonic model of quarks.

Also, the obtaining of the mentioned values for $\rho_k^q \geq 0.8\text{x}10^{18}$ kg/m^3 as specific 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 (~ $4\text{x}10^{17}$ kg/m^3) is specific also to the value of surface density of a Strange Quark Star, i.e. the density of quark matter at zero pressure [44], and with the conclusion that if a quark matter with strangeness is bound, then energetically it can grow indefinitely by absorbing nucleons, (Witten [44]).

The use of the obtained minimal values of the current quark's volume for the quark star's density calculation 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 current quarks with upper mass (λ-, s- quarks), is partially in concordance with the hypothesis of strangelets' forming as bound states of roughly equal numbers of up, down, and strange quarks, [45], small enough to be considered particles, which can convert nucleonic matter to strange matter on contact, [46], and which can be cores of 'nuclearites', (strangelets with electron shell).

The conclusion that strange (anti)quarks' forming can result – conform to Eq. (27) also at cold, (inside a cold neutron star), is concordant to the fact that strangelets have been suggested as a dark matter candidate [44], 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 a half of an electronic neutrino with mass ~ $10^{-4}m_e$, (mass limit: 60 eV/c^2, [47]) and a radius equal to the quark's radius experimentally determined: $0.43\text{x}10^{-18}$ m, i.e. ~ $(1.3\div1.5)\text{x}10^{20}$ kg/m^3, the density of a quark star and of a black hole is limited in CGT to this maximal value, which is estimated in astrophysics for the center of a quark star, ($10^{18}\div10^{20}$ kg/m^3, [48]) 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 = $(10^{-1} \div 10^{-4})$m, [49]).

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 at the level of 60 eV, using a spectrometer that had a resolution of 50 eV, [47], this value being concordant to the CGT's model of electron and of beta disintegration [9-11].

4. The black hole's forming in CGT

4.1. The explaining of the Tolman–Oppenheimer–Volkoff limit in CGT

Regarding to the maximal possible density resulting from Eq. (17), it is observed that –because for $M_q \geq M_t >> M_s^{\bullet}$(486MeV), 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: $\rho_k^t = \rho_c \approx (M_q/\upsilon_q)_t = 4.26\text{x}10^{18}$ kg/m^3, ($M_q \geq M_t$), this being the maximal density inside a quark star conform to Eq. (17) obtained for ordinary temperatures by the CGT's model of quark, in the sense that a density increasing at values $\rho_k >$ ρ_c , supposes a decreasing of the current quark's volume, i.e. the quark's volume contraction by temperature' decreasing from ordinary temperature $T_n \approx 1$MeV/k_B to very low temperatures, $T \rightarrow 0$K corresponding to a "black hole" star resulting from a collapsed neutron star but by an intermediary state, of cold quark star.

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

$$r_z = r_z^0 = 0.03 \text{ fm and } l_z = l_z^0 = 0.12 \text{ fm, i.e.: } \upsilon_z^0 = \pi\, r_z^2 l_z \approx 0.34\text{x}10^{-48} \text{ fm}^3 \text{ , (Chpt. 2).}$$

For the case of a quark star made by current H_q -quarks ($M_H \approx 12.7$ GeV/c^2 ; $m_H \approx 12.3$ GeV/c^2 –values specific to CGT) which is transformed into a black hole, by the previous value of υ_z^0 it results a maximal density: $\rho_{bh}^0 \approx 8.79\text{x}10^{19}$ kg/m^3, at 0K and null internal vibrations, i.e. corresponding to that of a black hole having a mass $M_S = 0.46\ M_\odot$, conform to the known relation:

$$\rho_{bh} = 3c^6/32\pi G^3 M^2 = 1.85\text{x}10^{19}/M^2 \text{ with M in } M_\odot. \qquad (29)$$

If we consider the transforming of a cold quark star made of current masses of top quarks –the heaviest known quark, ($M_t = 175$ GeV/c^2 –in CGT [17]), taking into account its current mass deduced in the S.M.: $m_t = 173$ GeV/c^2 , calculating by υ_z^0 and Eq. (29) it results:

$$\rho_{bh}^0 = (173\text{x}10^3\text{MeV/c}^2):(\upsilon_z^0\text{x}175\text{x}10^3/17.37) \approx 8.98\text{x}10^{19} \text{ kg/m}^3.$$

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 Proto-Universe, transformed into a hot Universe by gravitational confining of 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 relative different to that of some astrophysical calculations which- by the compactness limit: $R \geq 2.94GM/c^2$ - obtained a limit for the mean density of a star's core:

$\rho_c^* \simeq 5.80\times10^{15}(M_\odot/M_S)^2$ g·cm^{-3}, [50], (5.80×10^{18} kg/m^3 for a star's mass: $M_S \approx 1M_\odot$ and 2.8×10^{19} kg/m^3 for $M_S \approx 0.45M_\odot$). Conform to the mentioned Ref. [50], a lower density of a quark star's center is specific to $M_S > M_\odot$ which – by Eqs. (17) and (24), gives:

$$\rho_q = {m_q}/{\vartheta_q} = \frac{m_z}{\vartheta_z M_q}\left[M_q - \Delta_q\right] = \frac{m_z}{\vartheta_z}[1 - \frac{A_q}{M_q}\cdot e^{k_q\cdot\left(1-\frac{M_{S\bullet}^2}{M_q^2}\right)}] \cong \rho_c^0\left(\frac{M_\Theta}{M_S}\right)^2 \; [kg/m^3] \quad (30)$$

Eq. (30) indicates that a cold quark star with lower mass favors the forming of heavier quarks-phenomenon explainable by a lower internal temperature T_i in its center, corresponding to a cold forming of the heavy quarks clusters, favored by the temperature-dependent decreasing of the quark's repulsive pseudo-charge q_s .

In Ref. [51], by an equation of state (EOS) based on a MIT bag-like model of quark's confining, it was concluded that stars with $M_S \geq 1.7\ M_\odot$ are metastable, but in cold stars with $M_S \approx (1.6\div1.7)M_\odot$ quarks appear after about 15 s and thereafter, the star's central density increases for a further 15-20s, until a new stationary state with a quark-hadron mixed phase core is reached, for stable stars.

Eq. (30), with: $\rho_c^0 \simeq 5.80\times10^{18}$ kg/m^3, for the value: $\rho_t = 4.2\times10^{18}$ kg/m^3 –specific to a quark star with heavy bottom-like current quarks, gives: $M_S \approx 1.175M_\odot$.

Related to the value: $M_S \approx (1.6\div1.7)M_\odot$, by the same ρ_c^0 it results: $\rho_q \approx 2.26\times10^{18}$ kg/m^3.

This value corresponds by Eq. (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 cold v-quarks and c-quarks, (so – conform to CGT, to the c-quarks' forming from v-quarks) and is very close to the density of a confined mesonic pair: $N_\pi(\lambda^- \bar{s})$ with $M_N = (935\ MeV/c^2)$ resulting from a neutron, conform to Eq. (27a) specific to CGT, ($\rho(N_\pi) \approx 2.19\times10^{18}$ kg/m^3).

However, it has been found [50] that no causal EoS has a central density, for a given mass, greater than that for the Tolman VII analytic solution [52], which suggests a quadratic mass-energy density dependence on r corresponding to the ansatz:

$$\rho(r) = \rho_c[1 - (r/R)^2]; \qquad \rho_c \simeq 1.5\times10^{19}(M_\odot/M_S)^2\ kg/m^3, \quad (31)$$

with ρ_c - the central density: ($\rho_{max} \approx 0.(6)\times10^{19}$ kg/m^3 for $M_S \approx 1.5\ M_\odot$).

It can be observed that this theoretic result of Ref. [52], by Eq.(31) for $M_S^0 \approx 0.454\ M_\odot$, gives: $\rho_c \simeq 7.28\times10^{19}$ kg/m^3 –value which is relative 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, (null vibrations): $\rho_{bh}^0 = 8.98\times10^{19}$ kg/m^3, which corresponds to:

$\rho_c \simeq 1.85(M_\odot/M_S)^2\times10^{19}$ kg/m^3- given by Eq. (29).

The difference could be explained by the internal vibrations (which exist even at 0K- conform to quantum mechanics) which tends to 0 for black holes 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 a small inflation of the z^0-preon's volume, even at $T \approx 0$K –conform to the CGT's model.

So, according credibility to both results obtained by Ref. [50] and Ref. [52], it is possible to interpret the difference between these results as being given by a different degree of current quarks' compactness, generated by different values of internal temperature, (intrinsic quarks' temperature, generated by z^0 –preons' vibrations), in the quarcic network of the star, because the value: $r_k^z = 0.12$ fm was used in Eq. (24) as apparent value, obtained by a radius of the nucleon's kerneloid (of its impenetrable volume): $r_i^n = 0.44$ fm –corresponding to the case of a nuclear network at ordinary nuclear temperature, r_i^n decreasing at lower temperatures.

It must be mentioned that is not well known the mass limit that a neutron star can possess before further collapsing into a black hole. In 1939, by neglecting nuclear forces between neutrons, using the 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 called 'the TOV limit', (Tolman–Oppenheimer–Volkoff, [53; 54]). Using an equation of state P(ρ) 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 greater than $M_{TOV} = 0.7\ M_\odot$, the corresponding maximum mass before collapse being with ten percent greater than this, ($M_S^0 \approx 0.77\ M_\odot$, [54]). So, the stars 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, a different estimate put the upper mass for neutron stars which are not collapsed into a black hole in a range from 1.5 to 3 solar masses, [55].

It can be observed that the density of a black hole corresponding to the TOV limit ($M_S^0 = 0.7\ M_\odot$) by Eq. (29), i.e.: $\rho_{bh}^0 = 3.775\text{x}10^{19}$ kg/m^3, may be explained in CGT as corresponding to a black hole which resulted by 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 value: $\upsilon_z^i = 0.8\text{x}10^{-3}\text{fm}^3$, (instead of $0.34\text{x}10^{-3}\text{fm}^3$), which corresponds- in spherical model, to a radius: $r_z^s = 0.058$fm, and in a prismatic (cold) form: to an inflated volume: $\upsilon_z^i = \pi(3r_{ie})^2(12r_{ie})$ which corresponds to an apparently inflated volume of the quasielectrons' kerneloid, of radius: $r_{ie} = 1.33\text{x}10^{-2}$fm, given by "zeroth" vibrations of amplitude: $\delta r_{ie} = (r_{ie} - r_{ie}^0) = 0.33\text{x}10^{-2}$ fm, and to a real radius: $r_z^r = 3r_{ie} = 4\text{x}10^{-2}$fm of the real volume of the z_0 –preons.

So, conform to CGT, the calculated TOV limit $M_S^0 = 0.7\ M_\odot$, giving: $\rho_{TOV} = \rho_{bh}^0 = 3.77\text{x}10^{19}$ kg/m^3 by Eq. (29), results by the fact that the repulsive force of the vibrated z^0 -preons and of their quasi-electrons equilibrate the gravitation force by the repulsive scalar (pseudo)charge of the z^0 –preons' kerneloids having in this case- even at T≈ 0K, a behavior of impenetrable rest mass volume in report to identical or similar kerneloids.

In general, compact stars of less than 1.44 solar masses – the Chandrasekhar limit – are white dwarfs and compact stars weighing between that and 3 solar masses should be neutron stars.

The fact that –conform to known studies [55], in the interval: (1.5÷3) $M_\odot$, both a neutron star and a black hole may exist, (placing the TOV limit in this interval) can be similarly explained by the conclusion that the initial TOV limit: $M_S^0 = (0.7\div0.77)M_{\odot}$ corresponds in CGT to a black hole with maximal density given by an intrinsic temperature of quarks: $T_i \to 0K$ but with really inflated z^0 -preons, while at higher internal temperatures: $T_i > 0K$, the inflation (dilation) of the quark's volume is increased as consequence of z^0-preons' vibration energy ($\varepsilon_z = k_B T_i$), whose amplitude $\delta r_z \neq 0$ gives a radius of the apparent (inflated) volume of these z^0-preons of the same current quarks: $\upsilon_z^i(r_z^i)$ with $r_z^i = r_z^r + \delta r_z$, the current quarks having in this case a volume corresponding to a lower density: $\rho_{bh} < \rho_{bh}^0$ and implicitly –by Eqs. (29), (31) -to an upper M_S^0-mass.

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: $dP(r)/dr = - \rho(r)\cdot g(r)$, it is deduced that a higher gravitationally generated pressure could compress the internal 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 (or electronic neutrinos): $\sim (1.3\div1.5)x10^{20}$ kg/m^3 , in CGT.

It results also that the stars with $M_S < M_S^0 = 0.77\ M_{\odot}$ have dilated current quarks and z^0-preons compared to a BH having $M_S = M_S^0$.

4.2. Observations regarding the Equation of state at the neutron star's cooling

The static equilibrium specific to Ms^0- limit but also to the interval: $M_S^0 \div 3\ M_{\odot}$ -at $T_i > 0K$: $dP(r)/dr = - \rho(r)\cdot g(r)$, which 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 disturbance field generated in the local quantum "vacuum" by the vibration energy, ε_z , [10; 11], is relative equivalent to the considering of a binding energy in Ref. [55]: $E_B = (M_B - M_G)c^2$, (M_G –the total gravitational mass of the neutron star; $M_B = m_N N_B$ the baryonic mass of the star) with a relation between the initial and the final masses (before and after cooling by emission of neutrinos): $M_G \leq M_G^f$ and a linear increasing of M_B with M_G, (for $M_B > M_{Bmax}$ not existing solutions for TOV equation).

But instead of a polytropic form: $P = K\cdot\rho^{5/3}$ of EoS it results that P depends also to the intrinsic temperature T_i of the vibrated sub-particles (quarks, z^0 –preons), possible-in the form:
$P_i = (\rho/m_z)k_B T_i$, (ρ;T_i –the density and the intrinsic temperature of the current quarks or the quarks nuggets, given by the vibration of z^0-preons' kerneloids, of mass m_z), the proportionality $P \sim \rho^1$ being used in EoS specific to high densities, first discussed by Zeldovich [56].

It results –in consequence, that the gradually increasing of the star's density 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 Eq. (4), with $n \sim P_i$, (heavier clusters as internal pressure increases).

If the internal temperature of T_i of the current quarks of initial radius r_q^i decreases, it being a cluster of vibrated z^0- preons, it is contracted conform to : $P_i V_i = K_t T_i$, (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:

$$\upsilon_p^f = \upsilon_p^i + \Delta\upsilon_p = \upsilon_p^i(1+ \alpha_q\Delta T_i)\ . \qquad (32)$$

For the quarcic cluster the dilation constant α_q can be approximated by the aid of Figures 3 and 6, by the resulting conclusions that the nucleon's impenetrable radius r_i = 0.44 fm (experimentally obtained as radius of mechanic interaction) is given by a dilated current quark's radius: $r_q' \approx r_i/2 = (0.2\div0.22)$ fm, which corresponds to a volume: $\upsilon_q = (3.35\div3.38)\text{x}10^{-47}$ - to an associated temperature of the vibrated nucleon: $T = T_n \approx 1\text{MeV}/k_B = 0.6\text{x}10^{10}$ K and to a kinetic energy per neutron: $E_N = 1.6\text{x}10^{-13}$ J, (i.e. to an energy per kerneloid of z^0 –preon: $E_z = E_N(3\text{x}7.5\text{MeV})/54 = 1.3\text{x}10^{-16}$ J), corresponding to an intrinsic temperature: $T_i^n = E_z/k_B \approx 10^7$ K, while the current quark's volume: $\upsilon_q^0 \approx \pi r_q^2 l_q = 0.91\text{x}10^{-47}$ m, (of $r_q^0 \approx 0.09$ fm; $l_q^0 = 0.36$ fm) corresponds to an intrinsic temperature T_i^0 = 0K, (specific to a black hole), resulting that:

$$\alpha_q = \Delta\upsilon_q/\upsilon_q^0\Delta T_i = (2.44/0.91)10^{-7} \approx 2.7\text{x}10^{-7}\ K^{-1}.$$

For a star with $M_S^0 = 0.7M_\odot$ (mean density $\rho_{bh}^0 = 3.775\text{x}10^{19}$ kg/m^3) which may result by the conversion of a cold t-quark star with current top quarks formed by z^0 –preons with inflated volume to a value: $\upsilon_z^i = 0.8\text{x}10^{-3}\text{fm}^3$, (instead of $0.34\text{x}10^{-3}\text{fm}^3$, at T=0K) , Eq. (32) gives an increasing of its intrinsic temperature: $\Delta T_i = \Delta\upsilon_q/\alpha_q\upsilon_q^0 \approx 2\text{x}10^6$ K over 0K, with $T_i^c > \Delta T_i$ in the star's center and $T_i \to 0$K to its surface, resulting that –as in case of a neutron star, a black hole must have a dense solid crust, colder than the black hole's center.

The mentioned values of $\upsilon_i(0.44\text{fm}) = 0.3566\text{fm}^3$; $\upsilon_q = 3.35\text{x}10^{-2}\ \text{fm}^3$; $\upsilon_z^i = 0.8\text{x}10^{-3}\text{fm}^3$, correspond to a (semi)empiric relation using constituent masses: $m_k = (m_q = (^1/_3)m_p;\ m_z)$:

$$\vartheta_{ki} = \vartheta_{ni}^m \cdot e^{-K\left(1-\frac{m_k}{m_p}\cdot k\right)}; \qquad \text{k} = e^{l\cdot\left(1-\frac{m_k}{m_p}\right)}; \qquad (33)$$

$$\text{K} = 6.4; \quad \text{l} = 0.956; \quad \vartheta_{ni}(\text{m}_\text{p}) = \vartheta_{ni}(0.44\text{fm}) \approx 0.3566\text{fm}^3; \quad \text{m}_\text{p} \approx 1836\ m_e$$

So, it results that the transforming of a quark star with $3M_\odot > M_S > M_{TOV}$ into a black hole is made by an intermediary cooling step in which the initially existent current quarks are contracted with the simultaneously decreasing of their scalar repulsive charge- by the reduction of the z^0-preons' vibrations, (zeroth vibration existing also to 0K), 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 Eq. (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 central part, i.e. with an intrinsic temperature T > 0K.

However, for neutron stars with $M_S > 3M_\odot$ which are still 'hot', the gravitation force generates in their central part a high pressure which determines the forced fusion of current nucleon' quarks and their transforming into λ- and $\bar{s}$- quarks and thereafter- into heavier quarks specific to CGT: C_q , S_q , H_q , which- by cooling and contraction, obtain a density specific to a black hole.

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, [57] and it can be extrapolated for a dense star composed of "nuggets" of confined quarks, with mass $m_P >> m_H$, which- in this case, by its cooling becomes preon star, i.e. formed as network of z^0 –preons, because –conform to Eq.(17) in this case the ratio Δ_q/m_P is enough small to consider- by Eqs. (17), (24) that the resulting density remains (quasi)constant at $m_P >> m_H$.

Other arguments for this conclusion, are the next:

Compared to a quark star, whose static equilibrium in a classic (non-relativist) case, is given by:

$$dP(r)/dr = - \rho(r)\cdot g(r) \; ; \qquad (g(r) = G\cdot m(r)/r^2), \qquad (34)$$

and by an equation of state: $P = (\Sigma P^f - B) = (^1/_3)(\rho - \rho_B)c^2$; $(\rho c^2 = \Sigma\rho_f c^2 + B;\ \Sigma\rho_f c^2 = 3\Sigma P^f)$, 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: $\rho_B c^2 = 4B = 4x10^{14}$ - $g\cdot cm^{-3}$ [44] (neutron star's surface density), in the previous case –of a black hole forming from a quark star having $M_S = M_S^0 \approx 0.77\ M_\odot$ [54], conform to CGT the gravitational collapse is impeded by the repulsive field of scalar pseudo-charges q_s^e of the quasi-electrons' kerneloids which compose the internal z^0-preons, given by the "zeroth" vibrations of their super-dense centroids [12].

Also, 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 (Eq. (16)), it results that this pseudo-charge q_s is proportional to 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, the necessity of a higher star's mass for its transforming into a quark star with heavier quarks being explained, (Eq. (34)).

The expression of $\in_p = \rho c^2 = \Sigma\rho_f c^2 + B = 3P + 4B$ of EoS is explained- in consequence, in CGT, by the conclusion that the gravitation force must equilibrate not only the quarks' kinetic energy (diminished by the bag's pressure) but also the pressure of vibrated photons at the bag's surface, i.e. 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.: $r_s \approx \delta_q(l_v^z) \approx (0.01\div0.03)$ fm , (compared to ~ 1 fm for the current u/d-quark's attractive force).

It has been also noticed from Ref. (Haensel et al. 2007, [58]) that the resulting EoS: $\in_p = \in(P)$ can be approximated by a non-ideal bag model , in the form:

$$\in_p = a\,B + b\,P, \qquad (35)$$

with a and b - arbitrary constants. Conform to previous conclusions, in Eq. (36) we must take-in concordance with Eq. (16): $B = (m_P/m_n)B_n(T_i/T_i^n)$ with m_n ; B_n –the nucleon's mass and bag constant and $T_i^n \approx 10^7$ K –the nucleon's internal temperature at a vibration energy $E_v^n \approx 1$MeV.

Also, the constant a in Eq. (35) must take into account and the contraction of the star's cooled solid crust.

Comparing the cooling neutron star with a cooling metal drop, it results that –because the star's crust is cooled faster than the star's interior, it 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:

$$\Delta P \cdot dV(R) = \sigma_q \cdot S(R); \quad \Rightarrow \quad \Delta P = P_i - G\frac{M(R)}{R^2}\rho_c(R)\cdot\delta R = \frac{2\sigma_q}{R}; \quad (\sigma_q = \frac{F_n(y)}{2l_y}) \qquad (36)$$

(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' mass M, P_i decreases with R but increases with ρ_c , δR and σ_q.

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, supposed of the form (31), remained after neutron star's cooling, 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 that give the density of the neutron star's density –in this case, while at higher P_i –values the fusion of the u/d –current quarks can be realized, resulting λ - and $\bar{s}$- quarks having a higher q_s –pseudo-charge, ($q_s(s^+) > q_s(\lambda^-) > q_s(n)$) which by their strong interaction with $F_s(y) > F_n(y)$ increases σ_q and the star's crust thickness δR, 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 quarks, which in this case can explain the density' variation of the formed quark star or black hole star (for $R_S > R_{TOV}$).

5. Conclusions

The presented theoretical conclusions, based on a semi-empiric relation for the current quarks mass specific to CGT but with the constants obtained with 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 sum of theoretic (apparent) volumes of preonic kerneloids, it results a maximal density of the current quarks: $s^\bullet$, (s), $c^\bullet$, (c), $b^\bullet$, (b) and t , in the range $(0.8\div4.2)\times10^{18}$ kg/m^3 , 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 $(1.5 \div 4)\times10^{18}$ kg/m^3, [22] and with theoretic observations [50] which indicated that also the value of 1×10^{18} kg/m^3 is characteristic to a quark star.

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

Looking the possible structure of a quark star, by the preonic quark model of CGT, it resulted that the neutronic quarks can generate –inside a relative 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:

$N_e(2d + u) \rightarrow \bar{s}^- + \lambda^-$ and the forming of composite quarks with the structure: $C^-(\lambda^- - \bar{s}^- - \lambda^-)$ and $C^+(\bar{s}^- - \lambda^- - \bar{s}^-)$, respective: $S_q^-[(\lambda^- - \bar{s}^- - \lambda^-) + (\bar{s}^- - \lambda^- - \bar{s}^-) + (\lambda^- - \bar{s}^- - \lambda^-)]^-$ and: $S_q^+[(\bar{s}^- - \lambda^- - \bar{s}^-) + (\lambda^- - \bar{s}^- - \lambda^-) + (\bar{s}^- - \lambda^- - \bar{s}^-)]^+$, the forming of heavier quarks inside a quark star being also possible –conform to CGT, in the form: $D_q = n^3C_q$, $(n \geq 3)$.

It also results that the gradually increasing of the star's density 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 Eq.: $D_q = n^3C_q$, $(n > 3)$, with $n \sim T_i^{-1}$.
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, [57].

The resulting heavier cold quark stars could also explain at least partially the high quantity of the Universe's dark matter.

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: $1\div1.3$ MeV/c^2 [6], (approximately equal to that of an (e^-e^+) pair).

In consequence, it is 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 colour charge of the paired quarks (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 (preonic) kernel, of z^0-preons and an un-paired charged quasi-electron which gives its electric charge $e^* = (^2/_3)e$ surrounded by a photonic shell. Supposing that at a critical temperature $T_c \rightarrow T_{d,}$ (T_c –phase transformation temperature; T_d –the quarks deconfining temperature: $\sim 2\text{x}10^{12}$ 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 relative 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 8 quasielectrons) but being maintained inside the constituent quark's volume by the force generated by a potential of the form (1), i.e. by the total vortical field of the current quark, (Eq. 16). After a current quark' partial deconfining, its reconfining at $T < T_c$ could generate a quasi-crystal or amorphous state- similar to the so-named ‚glasma' in the S.M., [59; 60], 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 the possibility to explain as in CGT the forming of heavy quarks as tri-quark clusters of lighter quarks having a current mass higher than the sum of the lighter current quarks of its structure by the addition of a part of gluons of its gluonic shell, i.e.- by a amorphous of quasi-liquid state of its current mass.

The previous similitude make link between the CGT's model of quark star and proposed models of boson star, i.e. made of bosons with m_b –mass, as that of Ref. [61] 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 general relativity 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 $1.8x10^{19}$ 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 $4.8x10^{17}$ kg/m^3 –that corresponds in CGT to a relative contracted nucleonic current u;d- quark, (from $\upsilon_q = 0.0335fm^3$ to a volume: 0.0275 fm^3, giving –by Eq. (32), a decreasing of its intrinsic temperature: $\Delta T_i = \Delta\upsilon_q/\alpha_q\upsilon_q^0 \approx 8x10^5$ K under $T_i^n = E_z/k_B \approx 10^7$ K specific to a kinetic energy per neutron of ~1MeV).

Also, this similitude, correlated with the possibility to explain the neutron star's core transforming into a quark star in conditions of low temperature and high pressure, bring argument for the preonic model of quark specific to CGT.

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