An unifying equation for almost all constituent quarks masses, of cold and hot genesis

Author: Arghirescu Marius* (OSIM; GCI-DLMFS-Romanian Acad.)
E-mail: maris3a@yahoo.com

Abstract:

Based on a Cold Genesis pre-quantum theory of particles and fields, (C.G.T.), which explains the constituent quarks and the resulted elementary particles as clusters of negatron-positron pairs ($\gamma(e^-e^+)$) forming basic z^0 -preons of ~34 m_e which generate preonic bosons $z_2(4z^0)$ and $z_\pi(7z^0)$ and constituent quarks in a preonic model, from two equations, one for the preonic quarks (u, d, s) and another for the heavy quarks (c-charm and b-bottom), a single unitary equation is obtained for the both mass variants: CGT/Souza and Standard Model, by using four parameters representing integer numbers from 0 to 3: $(k_1\ ;\ k_2) \leq 3$ (for the number of z_2- and z_π- preonic bosons); f = (1;2)- flavor number; n = (1÷4) –compositeness number, and a multiplication factor: $\left|2n-1-2^{(n-1)}\right|$ depending on n, the value n=4 giving a predicted quark, of mass ~15 GeV/c^2.

Keywords: preons; quarks; flavor; cold genesis; unitary equation; Standard Model

Introduction:

In the Standard Model (S.M.), it is known the constituent quark model, with a valence current quark (u-up, d-down, s-strange) or (c-charm, b-bottom, t-top) with a current mass [1]: (1.8÷2.8; 4.3÷5.5; 92÷104) MeV/c^2, respective: (1.27; 4.18÷4.7; 173) GeV/c^2 and a gluonic shell formed by gluons and sea-quarks [1], the resulting effective quark mass being the constituent quark mass: m_u = 336, m_d = 340, m_s = 486 (MeV/c^2) respective: m_c = 1.55, m_b = 4.73, m_t = 177 (GeV/c^2).

The electric charge of u-, c-, t- quarks is +($^2/_3$)e and the electric charge of d-, s-, b- quarks is –($^1/_3$)e, the strong interaction of quarks being explained by so-named "color charge", the gluons having two opposed color charges, the gluon field between a pair of color charges forming a narrow flux tube (as a string) between them, (Lund's string model [2]).

In a Cold Genesis pre-quantum theory of particles and fields, (C.G.T., [9-12]), based on Galilean relativity, it results- as a more natural alternative, 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 also be formed '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 the 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:

$$Li7 + p^+ \rightarrow Be^* \rightarrow Be8 + b^0\ ; \qquad b^0 \rightarrow e^+ + e^-\ , \qquad m(b^0) \approx 34\ m_e\ , \qquad (1)$$

This reaction was explained in CGT by the conclusion that z^0-preon is composed by two 'quarcins', $c_0^{\pm}$, its stability being explained in CGT by the conclusion that it is formed as a cluster of an even number n = 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 $\Gamma_\mu = \Gamma_A + \Gamma_B$ generated around superdense centroids and given by 'heavy' etherons of mass $m_s \approx 10^{-60} kg$ and 'quantons' of mass $m_h = h \cdot 1/c^2 = 7.37x10^{-51}$ kg.

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

In CGT, the fractional charge of quarks is given by a quasielectron –for $e^* = \pm(^2/_3)e$, and by a quasielectron and an electron with degenerate mas, magnetic moment, attached to a neutral cluster of paired quasi-electrons.

The light and semi-light cold quarks which give the masses of the astro-particles results in CGT as superpositions of preonic bosons $z_2 = 4z^0$ and $z_\pi = 7z^0$ with almost the same symmetry ('star' and hexagon, figure 1, [10;11]), conform to a constituent quark' mass equation of the form:

$$M_q = M(m_{1,2}) + k_1 \cdot z_\pi + k_2 \cdot (k_1 - 2) \cdot z_2 ; \quad m_{1,2} = (m_1^+ ; m_2^-) \ ; \ k_1 = 0 \div 3); \ k_2 = 0 \div 2 < k_1 \qquad (2)$$

i.e: -(k_1 , k_2 = 0) ⇒ $q = m_{1,2}$; (k_1 = 1, k_2 = 0) ⇒ $q = r^{\pm}$, ("rark"- un-stable quark); (k_1 = 2) ⇒ $q = p^+ , n^-$; - (k_1 = 3, k_2 = 0) ⇒ $q = \lambda^{\pm}$; (k_1 = 3, k_2 = 1) ⇒ $q = s^{\pm}$; (k_1 = 3, k_2 = 2) ⇒ $q = v^{\pm}$.

The particle's mass results by eq. (2) in the approximation of the sum rule applied to the particle's cold forming, as consequence of the quantum fields' superposition principle applied to the particle's cold forming as sum of degenerate electrons, whose total vortical field Γ_v can explain also the nuclear force $F_n = -\nabla V_n(r)$, [10, 11].

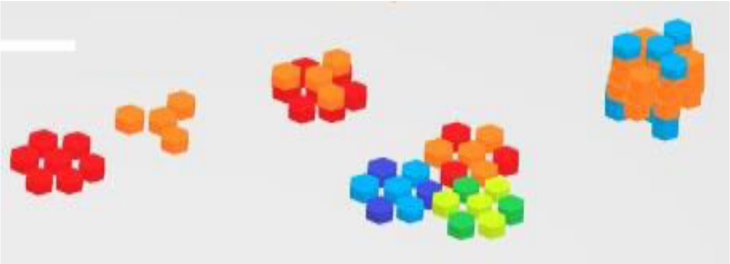

Fig. 1, *The cold forming of semi-light quarks from $m_{1;2}$ light quark and z_2- , z_π -preonic bosons, (3D)*

For the constituent quarks heavier than the nucleonic quarks it was found the next structure [16]:

a) $m_s = 0.5\ GeV/c^2 = 978.5\ m_e$ ($\approx m_s^* = 987.8\ m_e$, ~$0.504 GeV/c^2$) -the mass of s-quark;
b) $m_c = 1.7\ GeV/c^2 = 3326.8\ m_e$ –charm quark's mass used by de Souza [17], and:
c) $m_b \approx 5$ GeV –bottom quark's mass used by de Souza [17],
d) $m_t \approx 175$ GeV, the t-quark's mass, with current mass resulting as prismatic cluster:

$$t^{\pm} = (7\text{x}5)m(b^{\pm}) = (17(b\bar{b}) + b^{\pm}), \qquad \text{(super-heavy quark)} \tag{3}$$

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

$$M_n^{¤}(q_n) \approx M_1 \cdot 3^{n-1}\,; \quad q_n = [(q\bar{q})q]_{n-1} \tag{4}$$

obtained by Karrigan Jr. [18] for quarks of S.M., (for masses: $m_2^{\bullet} = m_c^{\bullet} = 1.55$ 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 the form:

$$M_n(q_n^c) \approx 3^{n-1}\left[M_1 - \frac{z^0}{3}(2n-3)\right],\ (n > 1); \tag{5a}$$

(n- compositeness number), or- taking into account and the loosing of some internal bosons (photons –in CGT and gluons in S.M.) corresponding to the binding energy of composite m_n – quark forming, by the approximated form:

$$M_n(q_n^c) \approx 3^{n-1}\left[M_1 - \frac{z^0}{3} ln(3^{n-1}3^{n-2})\right] \tag{5b}$$

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^+ (charm) and b^- (bottom) as de-excited states of the triplet $M_n(q_n^c)$ with mass: $M(c^*) = 3M_v^*(v^+) = 3363.6\ m_e$, (1.718 GeV/c^2), and respective: $M(b^{*\pm}) = 3M_c \approx 5.1$ GeV/c^2, (q^* -'cold' quark), by the next de-excitation reactions specific to Eqs. (5), (with the released mass proportional to the quarks' binding energy):

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

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

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

$$c(1700) \rightarrow c^{\bullet}(1561) + \pi^0(2z_2);\ b(5000) \rightarrow b^{\bullet}(4756) + z_6(2z_{\pi});\ s(504) \rightarrow s^{\bullet}(486) + z^0 \tag{7}$$

i.e. by an equation which explains the reactions (7) of the form:

$$M(q_n^{\bullet}) \approx 3^{n-1}\left[M_1 - [\delta^{\bullet} - \frac{z^0}{3}(n-2)]\right] \tag{8a}$$

with: $[(M_1 - \delta^{\bullet}) = (2m_s + m_v - z^0)/3]$, ($\delta^{\bullet} = 52.45$ MeV/c^2)

or- taking into account the increasing of the vortical field with $m_n^c(q_n^{\bullet})$, approximately by:

$$M_n^c(q_n^{\bullet}) \approx 3^{n-1}\left[(M_1 - \delta) + \frac{z^0}{3}\ln\,3^{n-2}\right]\,; \qquad (\delta = 55\ \text{MeV/c}^2) \tag{8b}$$

the value $\delta \approx 55$ MeV/c^2 being obtained by taking $M_n^c(n = 3) = 4.73$ MeV/c2 (the known experimental value), giving: n = 2 → $m(q_2^{\bullet})c^2 = 1.557$ GeV $\approx m(c^{\bullet})$; n = 3 → $m(q_3^{\bullet})c^2 = 4.728$ GeV, values almost equal to the known masses of the constituent charm- and bottom- quarks experimentally determined, (1.55 GeV/c^2, respective: 4.73 GeV/c^2).

In another paper of the author [19] , it was obtained –from Eqs. (5b) and (8b), a single equation for the masses of the composite constituent quarks of cold genesis (Souza/CGT variant) and of hot genesis (S.M.'s variant), in the form:

$$M(q_n^f) = 3^{n-1}\{m_v - (2-f)\delta - (z^0/3)\ln[3^{(2n-3)}/3^{(2-f)(3n-5)}]\} \qquad (9)$$

in which: $m_v = m(v^{\pm}) \approx 574$ MeV/c^2; $\delta = 55$ MeV/c^2 and $f = f_q = (f_l = 1; f_2 = 2)$ -flavors numbers of composite quarks: $q_n^{\bullet}$(S.M.) and q_n^s (CGT), (named 'quarkonics', in CGT [19]).

Eq. (9), by $f = |f_q| = 1$ retrieves Eq. (8b) for $m(q_n^{\bullet})$ and by $f = |f_q| = 2$ it retrieves Eq. (5b) for $m(q_n^s)$.

2. The obtaining of a single equation for almost all composite quarks masses

The possibility to unify the equations (2) and (9) in a single equations for all light, is to write in Eq. (9) the Eq. (2) instead of m_v and $(z^0 + \beta)$ instead of δ, ($\beta = 37.63$ MeV/c^2), and to multiply the last part of Eq. (9) with $|\alpha_q|$, α_q being the sum: $\alpha_q = (2n - 1 - 2^{n-1})$, which gives: $\alpha_q = 0$ for $n = 1$, $\alpha_q = 1$ for $n = 2$ or 3 and $|\alpha_q| = 1$ for $n = 4$. It results the equation:

$$M_q(q_n^f) = 3^{n-1}\left\{[M_{1,2} + k_1 \cdot z_\pi + k_2 \cdot (k_1 - 2) \cdot z_2 - z^0(2-f)] - [\beta(2-f) + \frac{z^0}{3}\ln\frac{3^{(2n-3)}}{3^{(2-f)(3n-5)}}] \cdot |2n - 1 - 2^{(n-1)}|\right\}; \qquad (10)$$

$$M_{1,2} = M(m_1^+; m_2^-);\ k_1 = 0 \div 3;\ k_2 = 0 \div 2 < k_1;\ f = (1;2);\ n = 1 \text{ if } (k_1 + k_2) < 5;\ n = (1 \div 4) \text{ if } (k_1 + k_2) = 5$$

($M_{1;2} = 69.5$ MeV/c$^2 \approx (1/\alpha)m_e$; $\beta = 37.63$ MeV/c^2; f = 1, for S.M.'s variant, being applicable only for $k_1 > 2$).

It is observed that for n = 1 it is retrieved the Eq. (2) for the preonic quarks, (light and semi-light), and for $(k_1 + k_2) = 5$; $n > 1$, it is retrieved Eq. (9) and taking $e^{(2n-3)}/e^{(2-f)(3n-5)}$ instead of $3^{(2n-3)}/3^{(2-f)(3n-5)}$ there are obtained –with f = 1, 2, the Eqs. (5a) and (8a) corresponding to the de-excitation reactions (6) and (7) and to the sum rule.

The differences per m_v-quark resulting between Eqs. (5a) and (5b):

$\Delta_q = -(z^0/3)[\ln 3^{(2n-3)} - (2n - 3)] < 0$ can be explained in CGT by the conclusion that a bigger mass of composite quark imply an increasing binding energy between their constituents (smaller quarks) determined by a higher vortical attractive force per v-quark and an increased quantity of loosed internal photons per v-quark, at their confining into a composite quark.

The difference per m_v-quark resulting between Eqs. (8a) and (8b):

$\Delta_q^{\bullet} = (z^0/3)[\ln 3^{(n-2)} - (n - 2)] > 0$ can be explained in CGT by the conclusion that a bigger mass of composite quark formed by de-excitation of its metastable state imply a mass-depending decreasing of the quantity of loosed internal photons per v-quark, at the de-excitation of the meta-stable composite quark, determined by a higher vortical attractive force per v-quark for a higher mass of the metastable composite quark.

This interpretation results by the fact that the quantity $(z^0/3)\ln 3^{(n-2)}$ is subtracted from the quantity $\delta = 55$ MeV/c^2 is subtracted from the constituent mass of the v-quark, the difference (δ - (z^0/3)ln$3^{(n-2)}$) being given by two z^0-preons and a quantity of released photons, the value: [δ - $2z^0$ - (z^0/3)ln$3^{(n-2)}$] representing a quantity of released photons per v-quark, (the value $2z^0$ representing the mass of two released z^0-preons per v-quark).

The current masses of quarks results in CGT according to a semi-empiric relation inspired by the proportionality: $M_p^2 \sim (m_{q1} + m_{q2})$, specific to the Gell-Mann-Oakes-Renner relation [20]), resulting as ansatz in the form [21]:

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

with $M_{s\bullet} = M_s^{\bullet}$(486MeV) – the constituent mass of $s^{\bullet}$ –quark. The constants A_q, k_q, were obtained by taking: m_d = 7.5 MeV/c^2 [21] and m($s^{\bullet}$) = 91 MeV/c^2 [21], ($\Delta_q = M_s^{\bullet}$ -m($s^{\bullet}$) = 395 MeV/c^2), resulting that: $A_q = \Delta_{s\bullet}$ = *395* MeV/c^2 ; k_q = *0.182*, and: $m_{c\bullet}'$ = 1091 MeV/c^2 , $m_{b\bullet}'$ = 4257 MeV/c^2.

It results the next Table, (d-quark = de-excited quark):

Table 1 : The theoretic masses of quarks in variants: S.M.'s and Souza/CGT, (Eq. (10))

Quark/index	n	k_1	k_2	f	Constituent mass MeV/c^2	Known SM's mass MeV/c^2	Current mass MeV/c^2 (CGT/(SM)	Variant
mark, ($m_{1;2}$)	1	0	0	2	69.1; 70.4		≈ 1.(6)	CGT
rark ($r^{\pm}$, un-stable)	1	1	0	2	191.6		3	CGT
park/nark, (p; n) (u/d)	1	2	0; 1	2	312; 313	336; 340	7.5 (3÷6)	CGT; SM
lark, λ	1	3	0	2	435		57.4	CGT
d-lark, $\lambda^{\bullet}$	1	3	0	1	417.6		47.2	CGT
sark, s	1	3	1	2	504		104	CGT
strange, $s^{\bullet}$	1	3	1	1	486.6	486	91;/(90÷130)	S.M.
vark, v	1	3	2	2	574		158	CGT
d-vark, $v^{\bullet}$	1	3	2	1	556.6		144.14	CGT
chark, c	2	3	2	2	1700		1233	CGT
charm, $c^{\bullet}$	2	3	2	1	1557	1550	1091; (1180÷1340)	SM
bark, b	3	3	2	2	5000		4527	CGT
bottom, $b^{\bullet}$	3	3	2	1	4728	4730	4257; (4130÷4340)	SM
fark, f_q (b $\bar{b}$b)	4	3	2	2	15000	-	14526	CGT, pred.
d-fark	4	3	2	1	14356.5	-	13882	CGT, pred.

Conclusions

Based on a Cold Genesis pre-quantum theory of particles and fields, (C.G.T.), based on Galilean relativity, which explains the constituent quarks and the resulted elementary particles as clusters of negatron-positron pairs ($\gamma(e^-e^+)$) forming basic z^0 -preons of ~34 m_e which generate preonic bosons $z_2(4z^0)$ and $z_\pi(7z^0)$ and constituent quarks in a preonic model, from two equations, one for the preonic quarks (u, d, s) and another for the heavy quarks (c-charm and b-bottom), a single unitary equation is obtained for the both mass variants: CGT/Souza and Standard Model, by using four parameters representing integer numbers from 0 to 3: $(k_1 ; k_2) \leq 3$ (for the number of z_2- and z_π- preonic bosons); f = (1;2)- flavor number; n = (1÷4) –compositeness number, and a multiplication factor depending on n, n=4 giving a predicted quark, of mass ~15 GeV/c^2.

The values of constituent quarks masses in the S.M.'s variant result by the CGT's unitary formula with discrepancy under 1%, excepting the case of the u/d-quarks, ($M_{u/d}$ = 312; 313 GeV/c^2 –in CGT).

It must be mentioned that also the Standard Model uses two massic variants of the constituent quarks, for baryons the constituent mass being higher than that known for mesons and of value depending on the choosed model, for example [22]:

$M_{u/d}$ = 362 MeV/c^2; M_s = 540 MeV/c^2; M_c = 1710 MeV/c^2; M_b = 5044 MeV/c^2,

The difference being explained by the conclusion that the mass of the strange quark, in presence of a heavy antiquark, is smaller, [22], (for example: 308 MeV/c^2 –for the u/d- quark, instead of 336÷362 –in the baryons' case, [22]).

References

[1] Patrignani, C. et al. (Particle Data Group) (2016) "Quarks", *Chin. Phys. C.,* **40**, 100001

[2] Andersson, B., Gustafson, G., Ingelman, G., Sjöstrand, T. (1983) "Parton fragmentation and string dynamics", *Phys. Rep.* ***97*** *(2–3): 31–145*

[3] Hanson, G. et al. (1975) *Phys. Rev. Lett.* ***35****, 1609*

[4] Per1, M. L. et al. (1976) *Phys. Rev. Lett.* ***35****, 1489*

[5] Herb, W. et al. (1977) *Phys. Rev. Lett.* ***39****, 252*

[6] Yndurain, F. (1995) "Limits on the mass of the gluon". *Phys. Lett. B.* ***345*** *(4): 524*

[7] Chipman, R.D., Jennings, L.D. **(**1995) *Phys. Rev.* ***132*** *728*

[8] ZEUS Collaboration. (2016) 'Limits on the effective quark radius from inclusive e-p scattering at HERA', *Phys. Lett. B.* ***757*** *468-472*

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

[10] Arghirescu, M. (2015) "The Cold Genesis of Matter and Fields", *Science P.G.* viXra:1104.0043

[11] Arghirescu M. (2016) "A preonic quasi-crystal quark model based on a cold genesis theory and on the experimentally evidenced neutral boson of 34 me*", Global J. of Phys.,* ***5*** *(1) 496-504*

[12] Arghirescu M. (2018) "A model of particles cold forming as collapsed Bose–Einstein condensate of gammons*", PAIJ, 2 (4): 260-267.*

[13] Hellman Olavi (1961) "A proposed elementary particle theory based on interacting classical fields", *Turun Yliopisto, Turku , (preprint)*.

[14] Krasznahorkay A..J. et al. (2016) "Observation of Anomalous Internal Pair Creation in 8Be: A Possible Signature of a Light, Neutral Boson*", Phys. Rev. Lett.* ***116****(4):042501.* arXiv: 1504.01527v1, [nucl-ex] 2015

[15] Sarri G., Poder K., Cole J., et al. (2015) „Generation of neutral and high-density electron–positron pair plasmas in the laboratory", *Nature Comm. ,* ***6****:6747, 23 April. 2015*

[16] Arghirescu, M., (2021) "An Explanatory Model of Heavy Quarks and Particles Generating resulted by a Cold Genesis Theory", *Theor. Phys. Lett., 9 (11): 190-217*

[17] Souza, M. E. (2011) "Calculation of almost all energy levels of baryons*", Papers in Physics, vol. 3, art. 030003.*

[18] Carrigan R. A. Jr. (1978) "Compound Quarks as an Explanation for the Apparent Quark Mass Spectrum*", Fermi Nat. Accelerator Lab., Batavia, Illinois, 60510, Jan. 1978*

[19] Arghirescu M. (2023), 'Quarks species in a cold genesis theory; theoretic implications of a Vortical quark model', *Phys Astron Int J.* **7**(3):195–207

[20] Gell-Mann, M., Oakes, R. J., Rcnner B. (1968) *Phys Rev. 175 2195*

[21] Arghirescu, M. (2024) The Structure and the Density of a Bare Quark Star in a Cold Genesis Theory of Particles. Journal of High Energy Physics , Gravitation and Cosmology , 10, 1933-1980.

[22] Maiani, L., Lecture 2: '*Exotic Hadrons. The constituent Quark Model'*, Galileo Galilei Inst., Firenze. Feb. 21-25, (2022). arXiv: hep-ph 2207.05141