SCIREA Journal of Physics
ISSN: 2706-8862
http://www.scirea.org/journal/Physics
September 18, 2023
Volume 8, Issue 5, October 2023
https://doi.org/10.54647/physics140579

The carted quarks-based equations for the proton magnetic moment, its countless configurations and a supposed spin propelling engine.

Emmanuel Saucedo-Flores, Víctor Manuel Rangel-Cobián
José Guadalupe Zuno No. 48, Industrial Los Belenes, CP 45101 Zapopan, Jalisco, México
Email: emmauel.saucedo@academicos.udg.mx; manuel.rangel@academicos.udg.mx

Abstract

The proton magnetic moment is computed by considering its quarks generated currents based in orbit-like circuits created as they are carted along by its hauler spin. Equations are derived for each quark magnetic moment for two possible rotations modes; needed quarks configurations for each rotation mode to obtain the experimentally determined proton magnetic moment numerical value are easily derived from the provided equations and a few examples are given. It is demonstrated that the proton quark configuration can be continuously adjusted, while maintaining the right proton magnetic moment, by relocating their rotation planes and/or their centers along the current circuits whilst keeping the up-down quarks separation and hence the Coulomb force among them. Additionally, it is shared the striking concept of the proton with 360° configurable quarks. Finally, a possible proton spin propelling engine based on the force among quarks is commented.

Key words: proton magnetic moment, the carted quarks currents, force among quarks.

The proton magnetic moment due to its quarks orbits magnetic moments

While the proton spins, its three quarks are carted along around the same axis as the proton and they can produce up to three internal currents if all involved rotating radii are different. Let's suppose that each quark gyrate in an orbit-like circle whose radii are identified as $d_{\mathrm{u1,p}}$, $d_{\mathrm{u2,p}}$, $d_{\mathrm{d,p}}$ (m) and defined by the distance from the center of the quark to the proton rotation *z*-axis as shown in Fig. 1 *a*); note the possible presence of up to three rotation planes parallel to the *x*-*y* proton plane with separations given by $P_{\mathrm{u1,p}}$, $P_{\mathrm{u2,p}}$, $P_{\mathrm{d,p}}$ (m); all quarks are coplanar in the $y = 0$ proton plane. A different quark configuration characterized by three radii from the proton center to the quark centers identified by $r_{\mathrm{u1,p}}$, $r_{\mathrm{u2,p}}$, $r_{\mathrm{d,p}}$ (m) with all quarks being carted along on the $y = 0$ proton plane and rotating around the *y*-axis is depicted in Fig. 1 *b*).

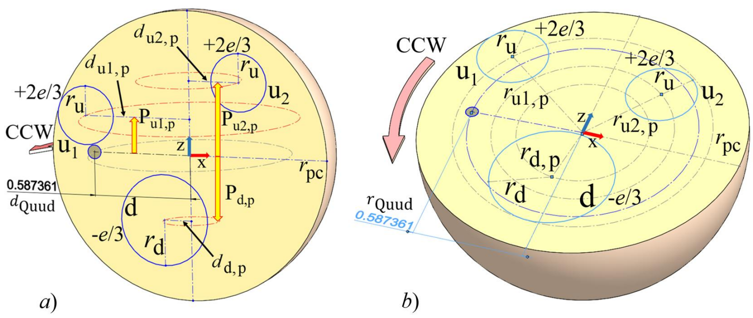

Fig. 1. At left, proton quarks rotating mode *a*) around the *z*-axis all of them located on the $y = 0$ plane at three normally different *z*-planes. Right, quarks rotating mode *b*) around the *y*-axis also being coplanar on the $y = 0$ plane at three normally different radii. The d_{Quup} and r_{Quud} terms will be defined in a bit.

Note that for the first configuration, a quark located on the vertical axis would not produce a magnetic moment; this will happen also for the b) case only for a quark placed at the proton center.

Observe that, for both rotation cases all quark centers are coplanar; non-coplanar configurations will be considered later. Only the CCW proton rotation will be used in this section. The quarks own spin is not taken into consideration for this analysis.

Let's now find out the magnetic moment for each quark in rotation mode *a*). The up quark u1, which has a charge of $+2e/3$, where e (C) is the electron charge, creates a carted current of

$$I_{\mathrm{Qu1,p}} = \frac{\text{charge}}{\text{one cycle rotation time}} = + \frac{2e/3}{2\pi d_{\mathrm{u1,p}}/c} \quad (\mathrm{A}) \tag{1}$$

where c (m/s) is the vacuum speed light; the involved current circuit has an area of

$$A_{\mathrm{Qu1,p}} = \pi\, d_{\mathrm{u1,p}}^2 \quad (\mathrm{m}^2) \tag{2}$$

then, its magnetic moment is given by

$$\mu_{\mathrm{p,u1}} = I_{\mathrm{Qu1,p}} A_{\mathrm{Qu1,p}} = + \frac{2e}{3} \frac{d_{\mathrm{u1,p}}}{2} c \quad (\mathrm{A \cdot m^2}) \tag{3}$$

Similarly, for the up quark u2 we obtain

$$\mu_{\mathrm{p,u2}} = I_{\mathrm{Qu2,p}} A_{\mathrm{Qu2,p}} = + \frac{2e}{3} \frac{d_{\mathrm{u2,p}}}{2} c \quad (\mathrm{A \cdot m^2}) \tag{4}$$

The down quark d has a charge of $-e/3$ (C) and its magnetic moment is given by

$$\mu_{\mathrm{p,d}} = I_{\mathrm{Qd,p}} A_{\mathrm{Qd,p}} = - \frac{e}{3} \frac{d_{\mathrm{d,p}}}{2} c \quad (\mathrm{A \cdot m^2}) \tag{5}$$

Then, adding up the above three expressions, the proton magnetic moment is given by

$$\mu_p = \mu_{\mathrm{p,u1}} + \mu_{\mathrm{p,u2}} + \mu_{\mathrm{p,d}} = + \frac{e}{2} \frac{2d_{\mathrm{u1,p}} + 2d_{\mathrm{u2,p}} - d_{\mathrm{d,p}}}{3} c \quad (\mathrm{A \cdot m^2}) \tag{6}$$

Now, given that the proton magnetic moment, as provided by NIST[ProtonMagneticMoment] [1], is

$$\mu_p = 1.410 \;\; 606 \;\, 797 \;\, 36 \;\; \mathrm{x} \;\, 10^{-26} \;\; (\mathrm{A \cdot m^2}) \tag{7}$$

(6) conduce to a mean carting distance of the total quark charge of

$$d_{Q_{\mathrm{uud}}} = \frac{2d_{\mathrm{u1,p}} + 2d_{\mathrm{u2,p}} - d_{\mathrm{d,p}}}{3} = 5.873 \;\; 606 \;\, 817 \;\; 833 \;\, \mathrm{x} \;\, 10^{-16} \;\; (\mathrm{m}) \tag{8}$$

A similar derivation for rotation mode *b*) in Fig 1 yields

$$\mu_p = \mu_{\mathrm{p,u1}} + \mu_{\mathrm{p,u2}} + \mu_{\mathrm{p,d}} = + \frac{e}{2} \frac{2r_{\mathrm{u1,p}} + 2r_{\mathrm{u2,p}} - r_{\mathrm{d,p}}}{3} c \quad (\mathrm{A \cdot m^2}) \tag{9}$$

and a mean quark carting radius to the proton center of

$$r_{Q_{\mathrm{uud}}} = \frac{2r_{\mathrm{u1,p}} + 2r_{u2,\mathrm{p}} - r_{\mathrm{d,p}}}{3} = 5.873 \;\; 606 \;\, 817 \;\; 833 \;\, \mathrm{x} \;\, 10^{-16} \;\; (\mathrm{m}) \tag{10}$$

Then, any appropriate choice of the three proton carting distances or radii would provide the same proton magnetic moment. This selection is strongly related to the considered radii numerical values for the proton charge radius, the up quark and down quarks, namely, r_{pc}, $r_{\mathrm{u,p}}$, and $r_{\mathrm{d,p}}$, respectively. On the examples provided below, we have chosen to use the following proton charge radius

$$r_{\mathrm{pc}} = 8.412 \;\; 356 \;\; 413 \;\; 42 \, \mathrm{x} \, 10^{-16} \;\; (\mathrm{m}) \tag{11}$$

since it provides a perfect match to the numerical value of the Planck constant[Planck_C] in

$$h = \frac{\pi}{2} r_{\mathrm{pc}} m_{\mathrm{p}} c = 6.6260 \;\; 7015 \;\; \mathrm{x} \;\, 10^{-34} \;\; (\mathrm{m}) \tag{12}$$

where m_{p} (kg) is the proton rest mass.

Rotation mode *a*) first calculation examples

Figure 2 shows two proton configurations with three carted quarks current circuits with at least one up quark considered to be tangent to the proton surface and the down quark radius $r_{d,p}$ (m) is chosen to be roughly 4/3 times bigger than the up quarks radii $r_{u1,p}$ and $r_{u2,p}$ (m). The two up quarks orbits are located in the z = 0 plane and have different rotation radius. In both cases, the down quark center point (d_{dp},P_{dp}) is placed equidistantly to the up quark centers by basically adjusting the plane of rotation separation to the *x*-axis P_{dp} while keeping the required radius of rotation d_{dp}. The P_{dp} tuning was aimed at producing a down-up quarks separation $s_{ud} \approx 0.0165$ (fermi). For these examples, quark sizes used are considered to be on the medium to small range. The charge $+e$ mean geometrical locations are indicated by an asterisk.

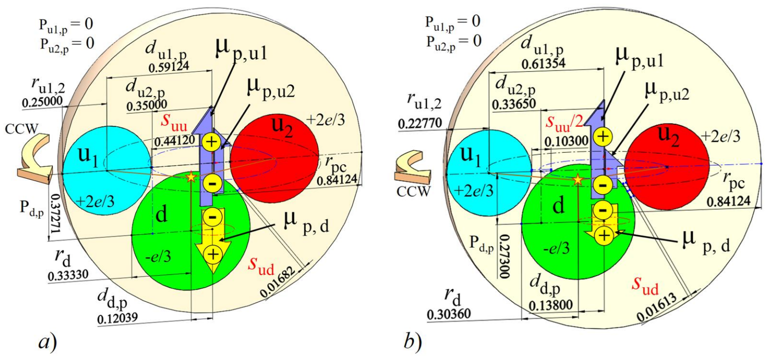

Fig. 2. Proton examples having quarks being carted on two planes with both up quarks on the z = 0 plane and current circuits such that $d_{u1,p} > d_{u2,p} >> d_{dp}$. Case *a*) has $r_{u1,2} = 0.25$, $r_d = 0.3333$, $P_{d,p} = 0.37271$ and $d_{dp} = 0.12039$. Case *b*) has $r_{u1,2} = 0.2277$, $r_d = 0.3036$, $P_{d,p} = 0.273$ and $d_{dp} = 0.138$. The $P_{d,p}$ values were chosen such that the down to up quarks separation s_{ud} is close to 0.0165. All dimensions are in fermis; magnetic moments arrows are just for illustration.

Using (3), (4) and (5), the quark magnetic moments for Fig. 2 *a*) example are

$$\mu_{p\_a),u1} = 9.823\ 188\ 300\ 6555 \text{ x } 10^{-27} = 8306.5(\pi d^2_{u1,p\_a)}) \quad (A \cdot m^2) \qquad (13)$$

$$\mu_{p\_a),u2} = 5.387\ 594\ 619\ 2663 \text{ x } 10^{-27} = 15145.2(\pi d^2_{u2,p\_a)}) \quad (A \cdot m^2) \qquad (14)$$

$$\mu_{p\_a),d} = -1.104\ 714\ 946\ 3217 \text{ x } 10^{-27} = -18465.4(\pi d^2_{d,p\_a)}) \quad (A \cdot m^2) \qquad (15)$$

which, with respect to the nuclear magneton nuclear_magneton μ_N ($A \cdot m^2$), have a ratio of 1.945, 1.067, and -0.219, respectively. Fig. 2 *b*) example one finds

$$\mu_{p\_b),u1} = 9.466\ 086\ 062\ 4447 \text{ x } 10^{-27} = 8619.8(\pi d^2_{u1,p\_b)}) \quad (A \cdot m^2) \qquad (16)$$

$$\mu_{p\_b),u2} = 5.603\ 738\ 831\ 3320 \text{ x } 10^{-27} = 14561.0(\pi d^2_{u2,p\_b)}) \quad (A \cdot m^2) \qquad (17)$$

$$\mu_{p\_b),d} = -9.637\ 569\ 201\ 7648 \text{ x } 10^{-28} = -21166.2(\pi d^2_{d,p\_b)}) \quad (A \cdot m^2) \qquad (18)$$

whose ratio with respect to the nuclear magneton are of 1.874, 1.109, and -0.191, respectively. Adding up provides

$$\mu_{\mathrm{p}\_a)} = \mu_{\mathrm{p}\_b)} = 1.410\ \ 606\ \ 797\ \ 36\ \ \mathrm{x}\ 10^{-26} = 13015.07\,(\pi d_{Q_{\mathrm{uud}}}^{2})\ \ (\mathrm{A}\cdot\mathrm{m}^{2}) \qquad (19)$$

see (7) and (8). The proton magnetic moment is approximately $2.79825\mu_N$.

For both examples, the Coulomb attractive force between the down and the up quarks, using a separation of $s_{\mathrm{ud}} = 0.165$ (fm) on both cases, amounts to

$$F_{\mathrm{ud}\_a)} = F_{\mathrm{ud}\_b)} = \frac{(-e/3)(+2e/3)}{4\pi\varepsilon_p\varepsilon_0 s_{\mathrm{ud}}^2} = -150650.9\ \ (\mathrm{N}) \ \ = -15.4\ \ (\mathrm{tf}) \qquad (20)$$

where ε_0 (F/m) is the vacuum permittivity, ε_p is the relative dielectric constant for the proton neutral matter and is supposed here to be 1.25; for the quarks matter, the supposed relative dielectric constant is infinite, so the Coulomb force vanishes inside of them. The force in (20) is close to the value reported as the minimum required to separate quarks, [2].

For the repulsive force among the up quarks, using $s_{\mathrm{uu}\_b)} = 0.206$ (fm) in Fig. 2 *b*) example, we obtain

$$F_{\mathrm{uu}\_b)} = \frac{(2e/3)^2}{4\pi\varepsilon_p\varepsilon_0 s_{\mathrm{uu}\_b)}^2} = +966.5\ \ (\mathrm{N})\ \ = 0.1\ \ (\mathrm{tf}) \qquad (21)$$

For Fig. 2 *a*) case, using $s_{\mathrm{uu}\_a)} = 0.4412$ (fm) gives

$$F_{\mathrm{uu}\_a)} = \frac{(2e/3)^2}{4\pi\varepsilon_p\varepsilon_0 s_{\mathrm{uu}\_a)}^2} = +210.7\ \ (\mathrm{N})\ \ = 0.02\ \ (\mathrm{tf}) \qquad (22)$$

Both cases deliver forces which are about two orders of magnitude smaller than $F_{\mathrm{ud},\_a)}$ in (20).

Second calculation comparison case for rotation mode *a*)

Figure 3 illustrates two proton quarks configurations with sizes on the large range. Both cases are based in a single carted up quarks current circuit with a charge of $+4e/3$ with $d_{\mathrm{u1,p}} = d_{\mathrm{u2,p}}$ and both up quarks tangent to the proton edge. In both examples, the down quark is placed on top of the proton rotating axis so that $d_{\mathrm{d,p}} = 0$ and its magnetic moment vanishes; the down quark in Fig. 3 *d*) is tangent to the proton edge, note that this seems to be the largest quark cross section possible for the proton. Considering that $d_{\mathrm{u1,2,p}\_c)} = d_{\mathrm{u1,2,p}\_d)}$ and $d_{\mathrm{d,p}\_c)} = d_{\mathrm{d,p}\_d)} = 0$ in Fig. 3, (6) collapses into

$$\mu_{p\_c)} = \mu_{p\_d)} = \frac{4e}{3}\frac{d_{u1,p\_c)}c}{2} = \frac{4e}{3}\frac{d_{u1,p\_d)}c}{2} = 1.410\,606\,797\,36 \times 10^{-26} \ (\mathrm{A \cdot m^2}) \quad (23)$$

which can be represented also as

$$\mu_{p\_c)} = \mu_{p\_d)} = (23137.9)(\pi d^2_{u1,p\_c)}) \ \ (\mathrm{A \cdot m^2}) \quad (24)$$

Again, the total charge mean geometrical sites are indicated by an asterisk.

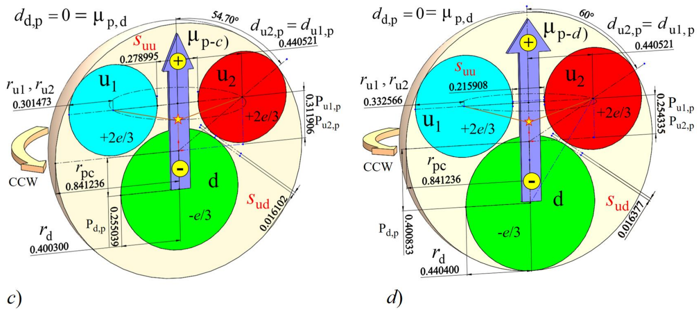

Fig. 3. Proton examples whose down quark is located on the rotation axis so that $d_{dp} = 0$ and are not able to produce a magnetic moment; also, both cases have $d_{u1,p} = d_{u2,p} = 0.440521$ and both up quarks are tangent to the proton edge. Case *c*) has $r_{u1,2} = 0.301473$, $r_d = 0.4003$, $P_{d,p} = 0.255039$, $P_{u1,p} = P_{u2,p} = 0.311906$. Case *d*) has $r_{u1,2} = 0.332566$, $r_d = 0.4404$, all quarks are tangent to the proton edge, $P_{d,p} = 0.400833$, $P_{u1,p} = P_{u2,p} = 0.254335$. Again, both cases were intended to make the down to up quarks separation s_{ud} close to 0.0165 (fm).

The aligned quarks centers cases which perform well for either rotation mode.

Figure 4 deploys two configuration pairs, *e*)_*f*) and *g*)_h) with all quarks centers arranged in a line which are able to produce the same magnetic moment for both rotation cases described above. These two quark layouts provide the shortest effective separation between the up quarks given by $s_{uu} = 2s_{ud}$ and hence its repulsion force would amount to approximately 7.5 (tf) for the same relative dielectric constant of the neutral proton as used for (20) to (22). Note that the up quarks layout in Fig. 4 *f*) have the same rotation radius and is given by

$$r_{Q_{uud}} = \sqrt{d^2_{u1.p} + P^2_{u1.p}} \ \ (\mathrm{m}), \quad (25)$$

see (10). The slight difference between *e*) and *f*) is that in *e*) there are two current circuits, one for each up quark while in *f*) there is only one current circuit for both up quarks.

In Fig 4 *g*) and *h*) examples all quarks are situated along the *x*-axis and create three concentric current circuits. In all configurations in Fig. 4, the mean charge geometrical site is at the down quark center.

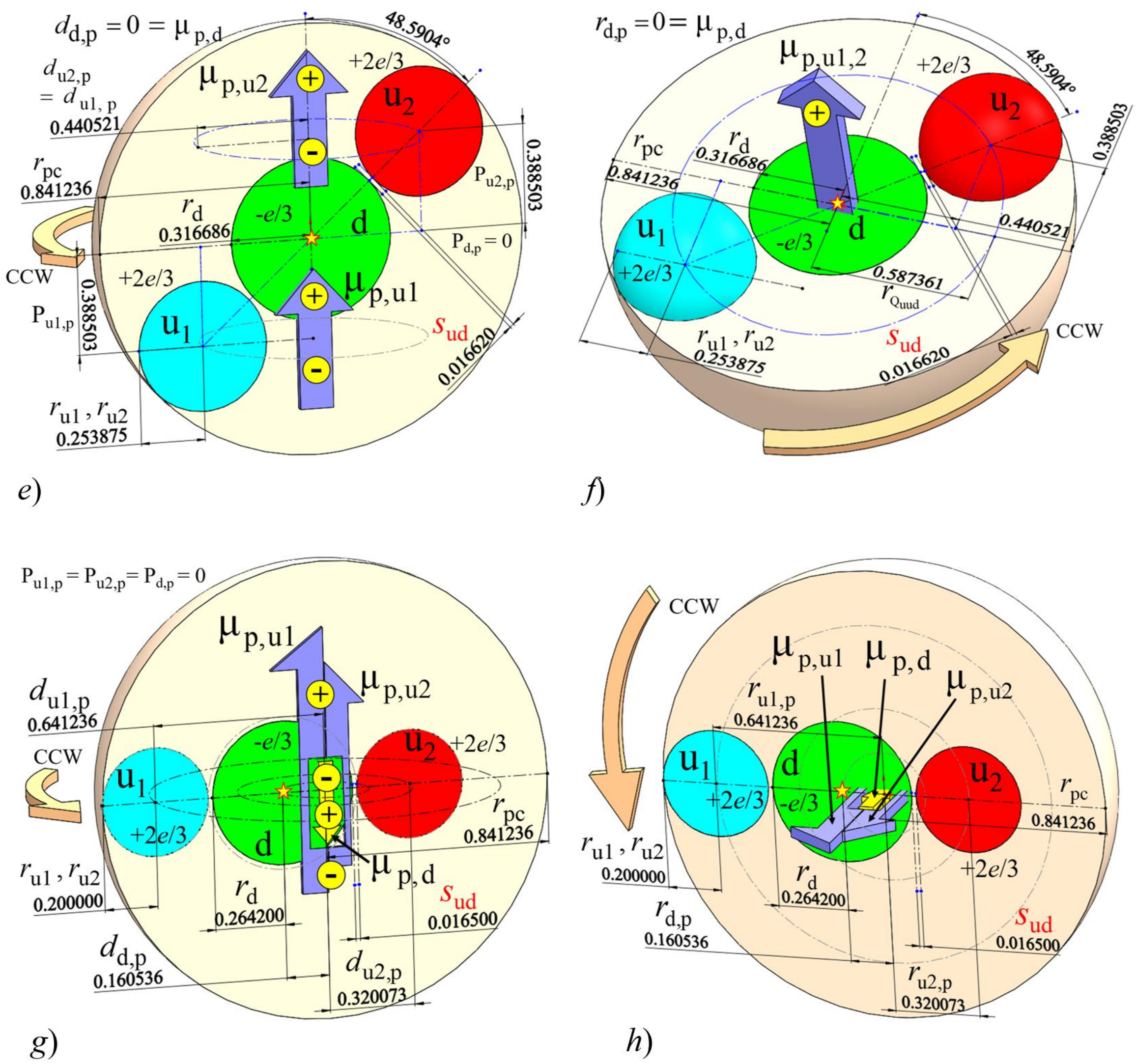

Fig. 4. Proton examples with all quark centers situated along a straight line able to give the same proton magnetic moment for the two rotation types. *e*) and *f*), quarks diagonal arrangement with the down quark located at the proton center. *g*) and *h*), all quarks located along the *x*-axis with the down quark located away from the origin; this configuration is possible only for small sized quarks.

Proton rotation mode *b*) examples

Figure 5 furnishes two proton quarks coplanar configurations with case *b*) rotation which comply with the required magnetic moment in (7). Medium sized quarks and three current circuits are used in Fig. 5 *i*), while big sized quarks and two current circuits are used in Fig. 5 *j*).

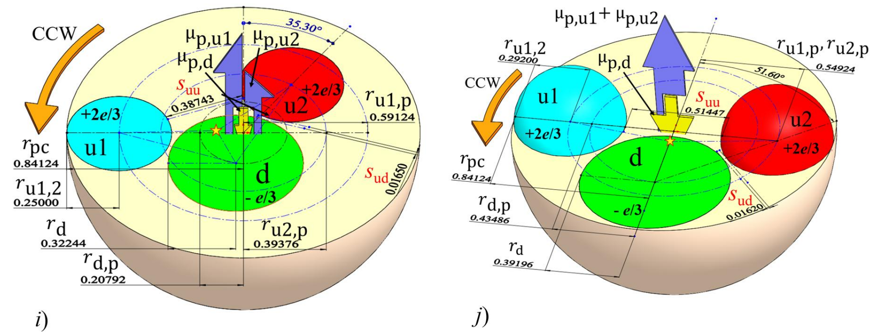

Fig. 5. Protons examples with case *b*) quarks rotation. *i*) Medium sized quarks with only one of them tangent to the proton edge, three current circuits are present and *j*) bigher sized quarks with all being tangent to the proton edge and only two current circuits are involved.

The proton with continuously configurable quarks through their rotation plane locations

Figure 6 shows a proton model with quarks whose centers are - in general - non-coplanar and are such that:

1) The center of the up quark u_1 is fixed to its current circuit circle and to the *x*-axis, so its location plane distance $P_{u1,p} = 0$. Also, its surface is tangent to a down quark "shell" of neutral proton matter which has a thickness of 0.0165 (fm). This shell does not need necessarily to have gluing properties but a proper dielectric nature to withstand the intense electric field between the up-down quarks.

2) The up quark u_2 center is coincident - but not fixed - with its current circuit path and is also made tangent to the down quark "shell" and its location plane distance $P_{u2,p}$ can be moved up or down while staying away from the u_1 up quark surface or from going out of the proton surface.

3) The down quark d center is kept coincident with its current circuit path and its location plane separation P_{dp} can be moved vertically at will; its tangency mates will produce an adjustment in the u_2 quark center location along its current circuit path; the d quark center site will also be relocated while keeping an eye on avoiding that its surface stays inside or at the proton surface. All quark current circuits radii $d_{u1,p}$, $d_{u2,p}$ and $d_{d,p}$ and the used quark radii $r_{u1,p}$, $r_{u2,p}$ are kept constant in the three study cases presented next.

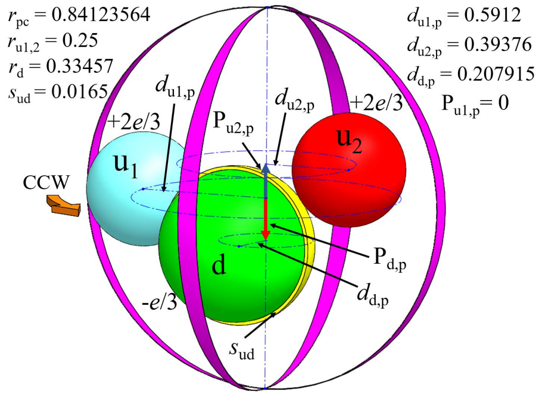

Fig. 6. Proton structural concept with non-coplanar quarks which can be continually adjusted and provide the same magnetic moment. This is just a variation of rotation mode *a*) so that the quarks are not necessarily coplanar.

Case A quark configuration study using $P_{u1,p}$ = 0 and $P_{u2,p}$ = + 0.15 (fm) while $P_{d,p}$ plane distance is adjusted from top to bottom positions is shown in Figure 7. The down quark top side limit is determined by its surface reaching the proton edge while its bottom side limit is due to the up quarks virtually getting in touch. Then, all the proton configurations in Case A study perform well from the magnetic moment point of view and might be possible; however, most of them could not be likely from other factors point of view like the repulsive force magnitude among the up quarks becoming similar to the force F_{ud} in (20) or one quark surface goes beyond the proton surface limit.

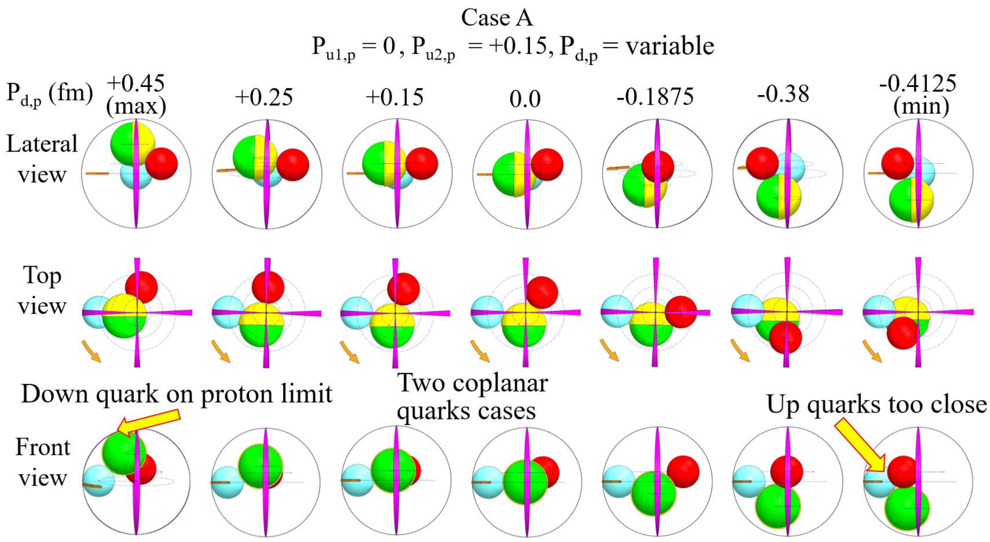

Fig. 7. Proton quarks configurations for study Case A using the parameter set indicated on top.

Figure 8 shows quark configuration Case B study using $P_{u1,p}$ = 0 and $P_{d,p}$ = - 0.15 (fm) while $P_{u2,p}$ plane distance is varied from bottom to top of proton. The u2 quark bottom incursion is limited by getting too close to the u1 quark; on the proton top side, the u2 quark reaches a point where its tangency mate and, hence, the due s_{ud} separation cannot be confirmed; additionally, the u2 quark becomes close to the proton size limit.

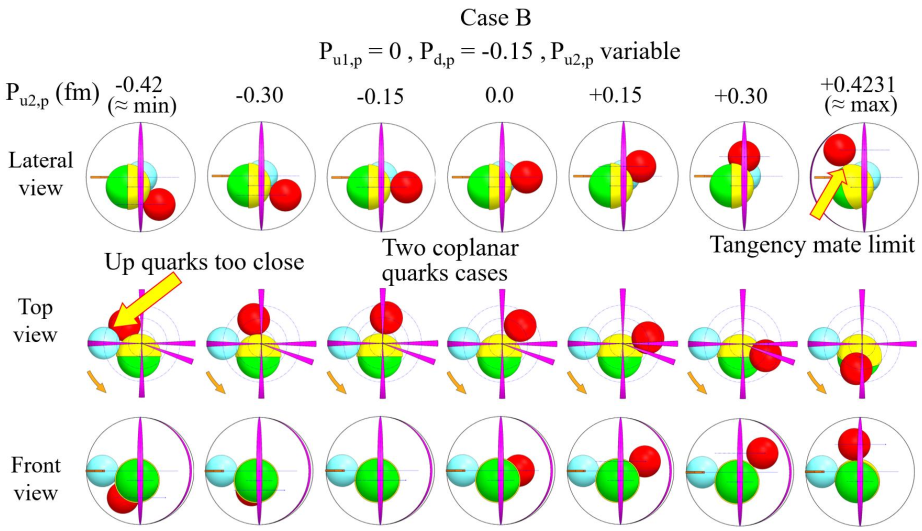

Fig. 8. Case B study of the proton with structurally adjusted quarks concept by varying the u2 up quark rotation plane $P_{u2,p}$ distance.

Case C proton quark possible configuration study is displayed in Figure 9. It was found that, for a given down quark rotation plane $P_{d,p}$ and keeping $P_{u1,p} = 0$, the u2 quark can occupy one of two different locations in the same rotation plane, $P_{u2,p}$, and circuit radius $d_{u2,p}$. The separation of the two possible u2 quark sites depends on the $P_{d,p}$ and $P_{u2,p}$ plane locations; this effect is illustrated for two $P_{d,p}$ plane positions in Fig. 9, both cases at the bottom proton region; above the $P_{d,p} \sim -0.2$ (fm) level, either one of the two quark sites is too close to the u1 quark or the second site is not detected at all.

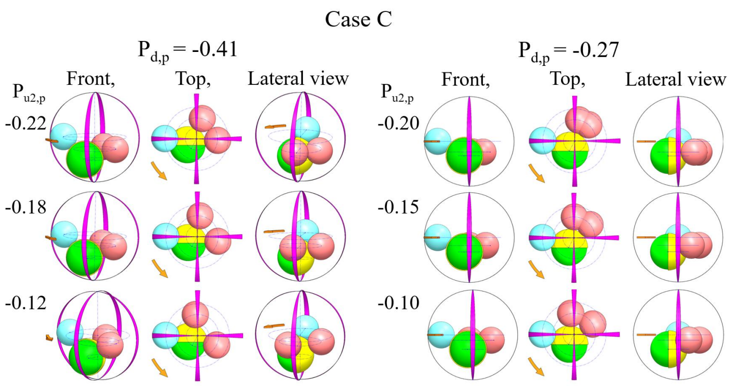

Fig. 9. Proton quarks configurations with u2 having two possible sites in the same $P_{u2,p}$ rotation plane for the two $P_{d,p}$ planes indicated on top.

Protons with 360° configurable quark locations and their tangential built-in shear forces.

Figure 10 portrays four possible proton cases whose up quarks can be placed all along their current circuit paths without modifying their magnetic moment. Also, the Coulomb forces among the up and down quarks are shown together with their centripetal and tangential components for both up quarks circuit paths. All cases are considered to be rotating CCW; the CW rotation alternatives would just imply that all tangential forces had to be reversed.

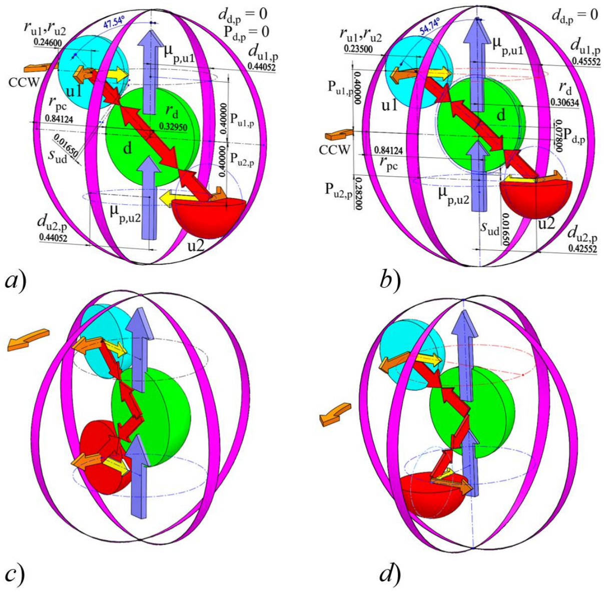

Fig. 11. Proton examples with 360° configurable up quarks for, *a*), equal current circuit radii $d_{u1,p} = d_{u2,p}$, the down quark at center of proton and both up quarks tangent to proton surface and, *b*), $d_{u1,p} \neq d_{u2,p}$, smaller sized quarks and the down quark placed slightly off center. *c*) and *d*) are alternative u2 configurations for *a*) and *b*), respectively. The tangential force acting on the up quarks would provide the proton a guessed spin propelling mechanism; the CCW or up rotation sense is given but the CW or down sense is also possible.

Conclusions.

Expressions for the proton magnetic moment calculation were presented. They are based on introducing the concept of quarks rotation current circuits produced by their carted tracks inside the proton. The calculated examples provide a perfect match to the experimentally determined proton magnetic moment. The Coulomb force among the quarks was calculated for a couple of cases; the needed force to detach the quarks was found to be of the order of 150,00 N (15 tf) using an up-down quarks separation of 0.0165 (fm). A few study cases of multiple proton quarks configuration were provided. Also, two examples of protons with 360° continually adjusted locations of quarks were disclosed along with the up quarks centripetal and tangential forces schematics. It was speculated that these forces may be a proton spin thrusting feature.

References

[1] Eite Tiesinga, Peter J. Mohr, David B. Newell, and Barry N. Taylor (2019), "The 2018 CODATA Recommended Values of the Fundamental Physical Constants" (Web Version 8.1). Database developed by J. Baker, M. Douma, and S. Kotochigova. Available at http://physics.nist.gov/constants, National Institute of Standards and Technology, Gaithersburg, MD 20899. Data retrieved on 03 July 2023

[2] Thayer Watkins, A Sensible Model for the Confinement and Asymptotic Freedom of Quarks https://www.sjsu.edu/faculty/watkins/quarkconfine2.htm