Stemming from within the nucleon, quarks are thus devoid of self-existence

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Abstract: A schematic model of nucleon genesis is propounded. It involves an interplay of centripetal and centrifugal spiral motions carrying quantized angular momenta, and driving the emergence of three intranuclear entities known as quarks. Hence, as Murray Gell-Mann advocated, quarks are not independent particles. This accounts for the absence of free quarks, and upholds the non-existence of free particles with fractional charge. Gell-Mann's persistent intuition was remarkable.

1. Introduction

Murray Gell-Mann and George Zweig independently proposed the idea of quarks in 1964, but it took many years before the "existence" of quarks was acknowledged. Gell-Mann was skeptical about quarks physical existence, and he did repeat his conviction in numerous occasions, often referring quarks as only "mathematical construct". The following citations are some examples:

At the 1972 NAL conference, Murray Gell-Mann ended his talk on quarks with the summary: "*Let us end by emphasizing our main point, that it may well be possible to construct an explicit theory of hadrons, based on quarks and some kind of glue, treated as fictitious, but with enough physical properties abstracted and applied to real hadrons to constitute a complete theory. Since the entities we start with are fictitious, there is no need for any conflict with the bootstrap or conventional dual parton point of view."* [1]

"As seemed probable from the outset, the quark model may be nothing more than a useful mathematical construct: The known hadrons – including dozens not yet discovered when the model was conceived – behave 'as if' they were composed of quarks. Quarks themselves may have no independent existence." [2]

"For the sake of a simple exposition, we begin our discussion of unitary symmetry with 'leptons' [l and $\bar{L}$], although our theory really concerns the baryons and mesons and the strong interactions. The particles we consider here for mathematical purposes do not necessarily have anything to do with real leptons, but there are some suggestive parallels." [3]

"It is fun to speculate about the way quarks would behave if they were physical particles of finite mass (instead of purely mathematical entities as they would be in the limit of infinite mass). ... A search for stable quarks of charge −1/3 or +2/3 and/or stable di-quarks of charge −2/3 or +1/3 or +4/3 at the highest energy accelerators would help to reassure us of the non-existence of real quarks." [4]

Gell-Mann's powerful and persistent intuition has never been acknowledged. As for example, Richard Feynman was convinced that quarks were "real particles". However, Gell-Mann thoughtful insight was unequivocal. Quarks are not "real particles", should we say not "independent particles". Nevertheless, they are somewhat "real entities", arising within the nucleon for NN binding purposes. In that sense, quarks are not only mathematical construct, they are dependent arising entities, rooted in the nucleon. As a consequence, quarks cannot be found outside nucleons since they have no independent existence. With no physical reality as conceived by modern physics, quarks are born within the nucleon itself. In fact, since the 1970s and despite tremendous efforts and energies at trying to break the proton in high energy colliders, no free quark was ever detected.

The emergence of quarks within the nucleon occurs via energy-momentum rearrangements, involving opposed spiral motions. However, envisaging quarks as mere emergent entities within the nucleon has important consequences, not only for particle physics and the Standard Model, but also for cosmology. As an example, the initial nucleon, or pre-nucleon (or prenon as will be called), becomes the precursor for the quark substructure, and not the opposite, since it precedes quarks emergence. Likewise, it becomes inappropriate to consider the existence of quark-gluon plasma, and the quark epoch in cosmology becomes arguable. Further, color confinement becomes a pleonasm for entities already born within a bound space.

2. Swirling up quark substructure from the spiral proton

The quark substructure stems from a subtle rearrangement of energy and momentum within the initial nucleon (prenon), whose structure is already spiral in nature. The inward spiral making up the initial nucleon has been described in length for the spiral proton at [5] and [6]. The subsequent outward triple-spiral process giving rise to the quark substructure is the result of internal energy and angular momentum splitting and redistribution, obeying conservation and quantization rules. These successive IN and OUT spiral operations give rise to elusory entities in the nucleon, named quarks by Gell-Mann.

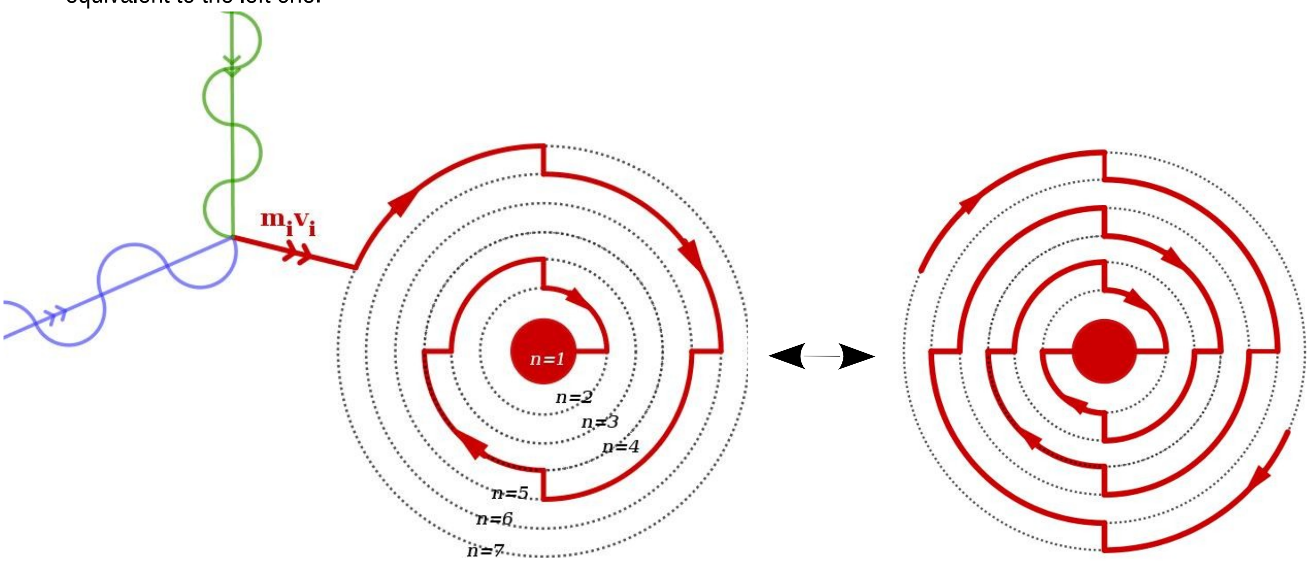
Step 1: The centripetal spiral generating the initial nucleon (prenon)

As described in [5,6] the spiral proton is an inward spiral (more precisely a double arm spiral), for which the angular momentum L_{IN} is quantized:

$$L_{IN} = mvr = \hbar\sqrt{n(n+1)} \qquad (1)$$

with n being the orbital angular quantum number and ħ the reduced Planck constant. This initial spiral proton, for which ~90% of the mass was found located within n=1 [6], is depicted in Fig.1 using two equivalent representations. Both depictions indicate the fusion of two distinct initial linear momenta.

Figure 1: Two equivalent representations of the spiral proton / initial nucleon. On the left side, the initial momentum $m_i v_i$ is the sum of two distinct incoming linear momenta in green and blue colors. The double spiral on the right hand side is equivalent to the left one.



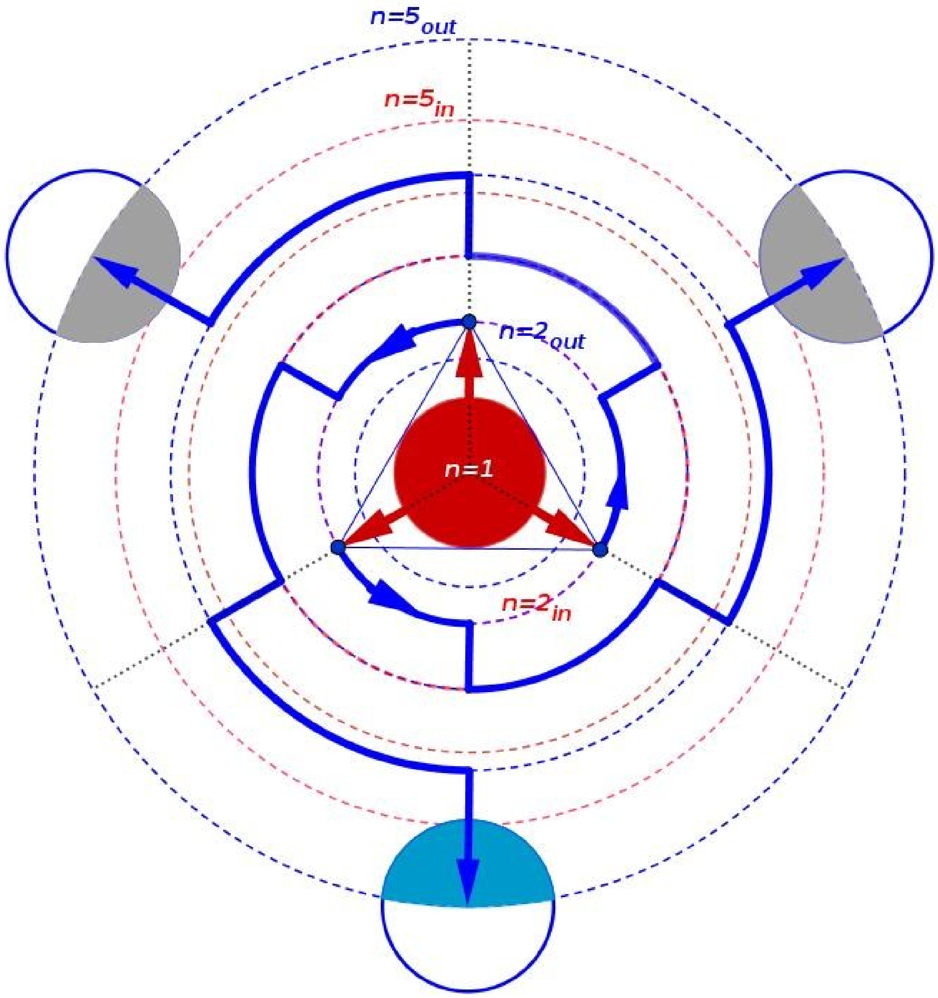
Step 2: The centrifugal threefold spiral giving rise to the quark substructure

The following step generating the quark substructure is an outward triple spiral originating from n=1 orbital (where most of the spiral proton mass-energy concentrates). This step necessarily requires a split and rearrangement of the mass and angular momentum. The outward angular momentum quantum step is proportional to $\hbar(3/2)^n$. This astonishing angular momentum and charge redistribution process leading to a triple outward spiral is the source of the quark substructure. The outward angular momentum motion is described by (for 1 quark):

$$L_{OUT} = mvr = \alpha\hbar \left(\frac{3}{2}\right)^n \qquad (2)$$

where α is the fine-structure constant. A depiction of the centrifugal threefold spiral generating the 3 quarks is presented in Fig.2

Figure 2: The red inward spiral producing the spiral proton from the initial momentum $m_i v_i$ follows the angular momentum progression expressed by Eq.1. The blue outward spiral giving rise to each constituent quark obeys the angular momentum progression expressed in Eq.2. Incoming and outgoing angular momenta follow different radius values. However, for n=2, the two radii seem to coincide and overlap. For clarity, only angular quantum numbers 1, 2 and 5 are noted. Quarks emerge at $n=5_{OUT}$.



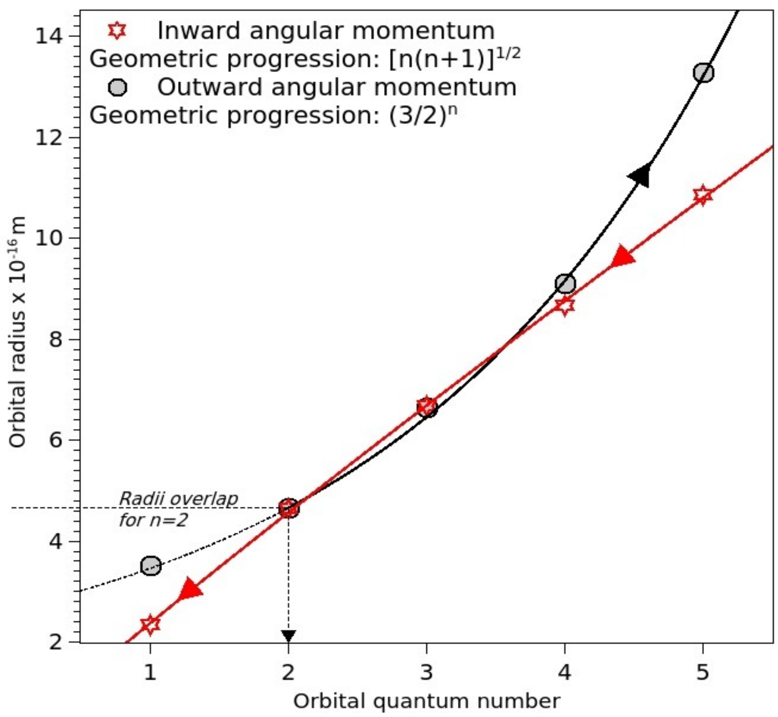
This phenomenal interplay of incoming and outgoing energy and angular momentum leads to the effective emergence of constituent quarks inside the nucleon. Quantized radii are presented in Table 1. Interestingly, radii seem to coincide at quantum number n=2 (and possibly n=3 ?) despite different geometric progressions. Overlapping radii constitute the bridge that allow cross over between the incoming and outgoing angular momenta, making the IN and OUT spirals possible.

Table 1: Radii followed by the quantized incoming and outgoing angular momenta

Angular Quantum number	**Inward Spiral Radius x 10^{-16} m R_{IN}**	**Outward Spiral Radius x 10^{-16} m R_{OUT}**
1	2.35	3.52
2	4.64	4.66
3	6.68	6.65
4	8.67	9.12
5	10.8	13.3

Fig.3 depicts the IN-OUT angular momenta radii which eventually lead to the stemming of u,d quarks within the prenon. Constituent quarks mature at radius $R_{OUT}\approx 1.3$ fm. However, the final positioning of current quarks is around 0.4 fm from the nucleon center, therefore a mechanism is further required to “pull” quarks closer to the nucleon center. This mechanism is provided by the gluons mediating the strong force, and will be discussed further in the text.

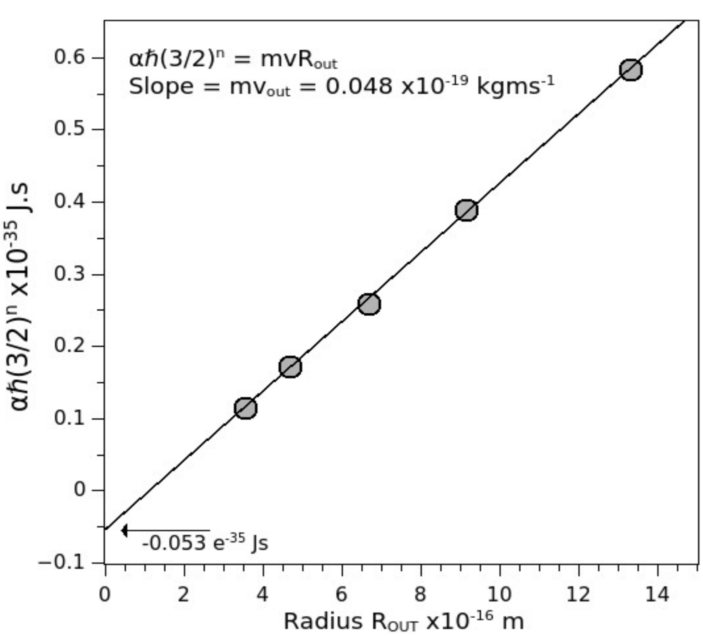
Figure 3: Progression of the incoming and outgoing spirals leading to the emergence of the constituent quarks within the prenon. Bridging of the two opposed momenta is enabled by a coincident radius at quantum number n=2, allowing cross over.



3. The outward spiral angular momentum

From the quantization of the outgoing angular momentum expressed in Eq.2, we can determine the momentum mv_{out} from the slope obtained in Fig.4 below.

Figure 4: Determination of the momenta mv_{out} associated with the outward spiral



From the graphically obtained numerical value mv_{out} =4.79 x10^{-21} kgms^{-1} and the quark rest mass m_o=1.22 x10^{-29} kg or 6.84 MeV (current quark mass) obtained at [7], we can determine the energy associated with this momentum:

$$E_{out} = \sqrt{p^2c^2+m_o^2c^4} = 1.806\times10^{-12}\,J = 11.27\ \text{MeV} \qquad (3)$$

The excess energy from the current quark rest mass provides ΔE≈4.43 MeV and covers the gluon mass carried along. Of particular interest is the ratio: $p^2c^2 / m_o^2c^4 = 1.717 \approx (\varphi^2/2)^2$ with φ=golden ratio. Likewise, the energy ratios 4.43 vs. 6.82 is close to 2/3.

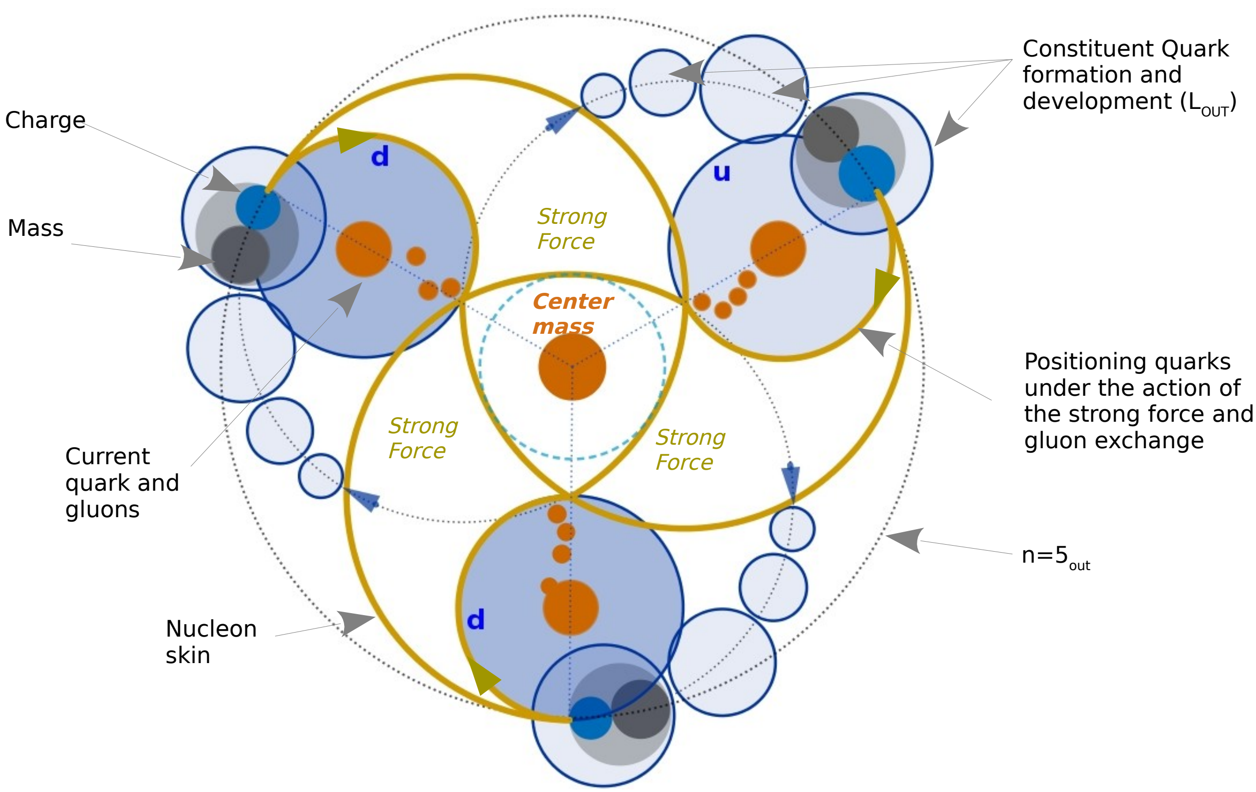
The mass-energy associated with the 3 quarks is therefore 11.27 MeV x3 ≈ 33.8 MeV, hence ~3.6% of the nucleon mass. The velocity associated with the outgoing angular momentum mvR_{out} can be determined from the Lorentz factor, and the expression (4) is obtained:

$$m=m_o\sqrt{\frac{1}{1-\frac{v^2}{c^2}}} \quad \Rightarrow \quad \frac{1}{v^2} = \left(\frac{m_o}{mv}\right)^2 + \frac{1}{c^2} \qquad (4)$$ giving $v=2.38\times10^8$ m/s or ≈ 0.8 c

4. Quarks positioning inside the nucleon

Quarks arise from the outward angular momentum L_{OUT} at orbital quantum number $n=5_{OUT}$ whose radius is around 1.3 fm. The gluon mass-energy carried along the formation of constituent quarks, allows the strong force to operate immediately through exchange of gluons with the nucleon central mass ($n=1_{IN}$), which behaves as a gluon reservoir. This gluon exchange sets the strong force in motion, as found by QCD, and pulls quarks further in toward the optimum distance. This optimum distance, which appears to be around 0.40–0.45 fm from the nucleon center (Fig.5), is of course subject to Heisenberg incertitude and NN binding environment.

Figure 5: Schematic of quarks emergence and positioning within the nucleon, as described above.



This interplay of centripetal and centrifugal spirals to generate quarks within the nucleon and further position them using mediating particles, is an astounding illustration of the way Nature utilizes very subtle mechanisms to produce the very basic building blocks of matter. Likewise, quarks and gluons operate at scales defying human conceptualization. These scales have been discussed at [8] and will be reexamined further in the text. Another way to illustrate the quark positioning principle in the nucleon is depicted in Fig.6 below.

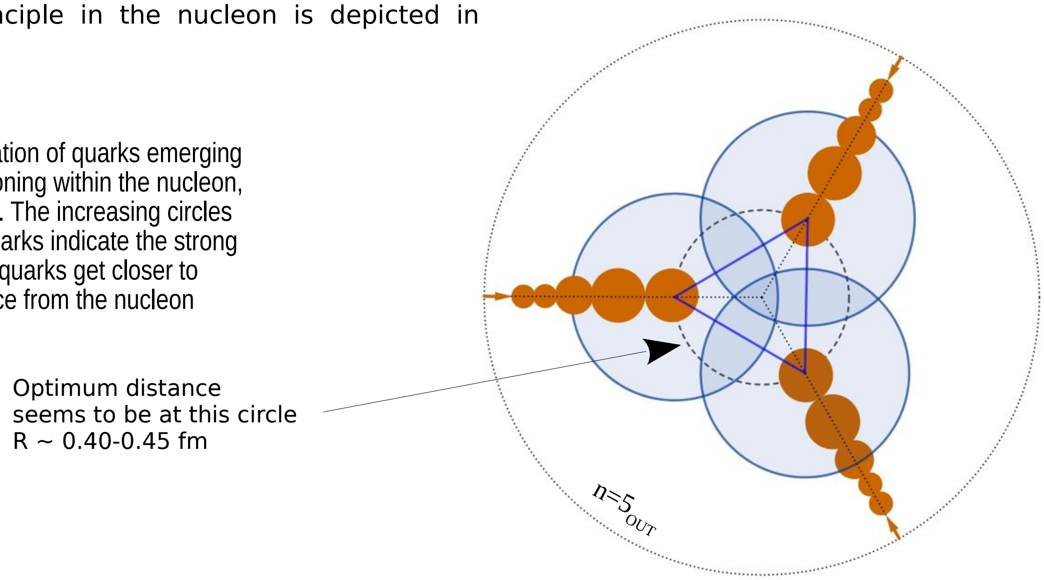


Figure 6: Illustration of quarks emerging @ n=5_{out} and positioning within the nucleon, as described above. The increasing circles depicting current quarks indicate the strong force increasing as quarks get closer to the optimum distance from the nucleon center.

5. Q-Q strong interaction vs. distance

The QCD framework postulates that the strong interaction between pairs of quarks does not diminish in strength with increasing distance, thus explaining why quarks cannot be pulled apart. However, that particular segment of QCD theory springs up from a misinterpretation, since quarks stem from within the prenon itself and are therefore rooted in the nucleon. Hence, quarks have no physical existence, appearing and disappearing within the nucleon, making color confinement principle irrelevant.

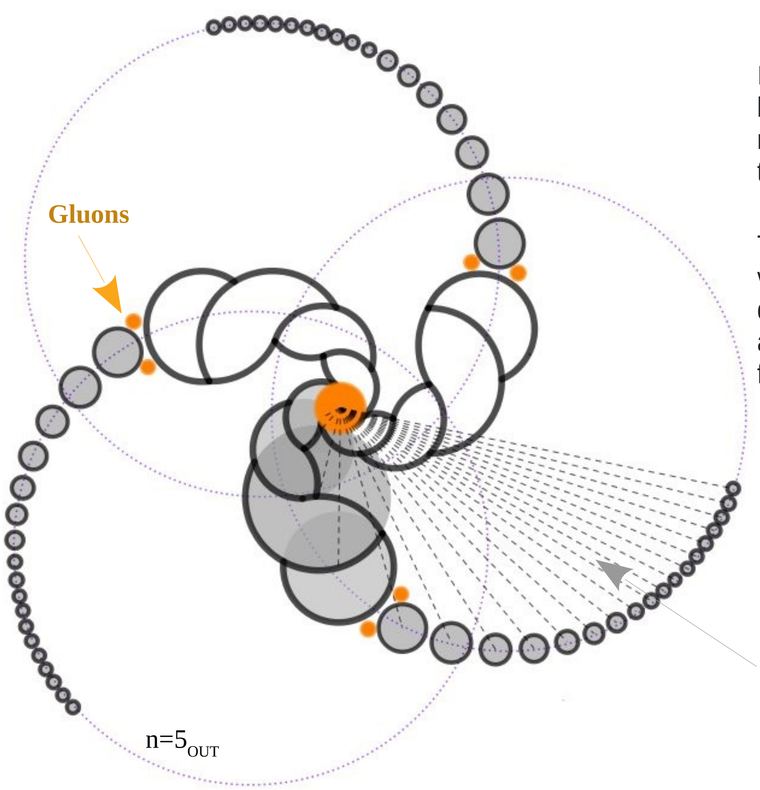


Figure 7: Illustration of strong interaction build-up as quarks move further in from orbital n=5_{OUT} under the influence of gluons mediating the strong force.

The torsional strains symbolize the binding force varying as a function of distance between quarks and the nucleon center. The circle areas are directly proportional to the strong interaction force.

Fig.8 below reproduces the strong force as a function of distance between quarks and the nucleon center. This force, which can adequately be fitted with a simple 4-parameter Laurentzian function, is comparable to other descriptive strong force potential such as the Nijim93 potential [9].

The potential well is centered around 0.41 fm, which corresponds to a distance q-q ≈ 0.7 fm. It seems that the optimum position for quarks from the nucleon center is around this value. When quarks emerge at orbital corresponding to radius $n=5_{OUT}$ the strong force seems to barely attain about 1-2% of its maximum value. However, this value is enough to pull quarks further in to their optimum position.

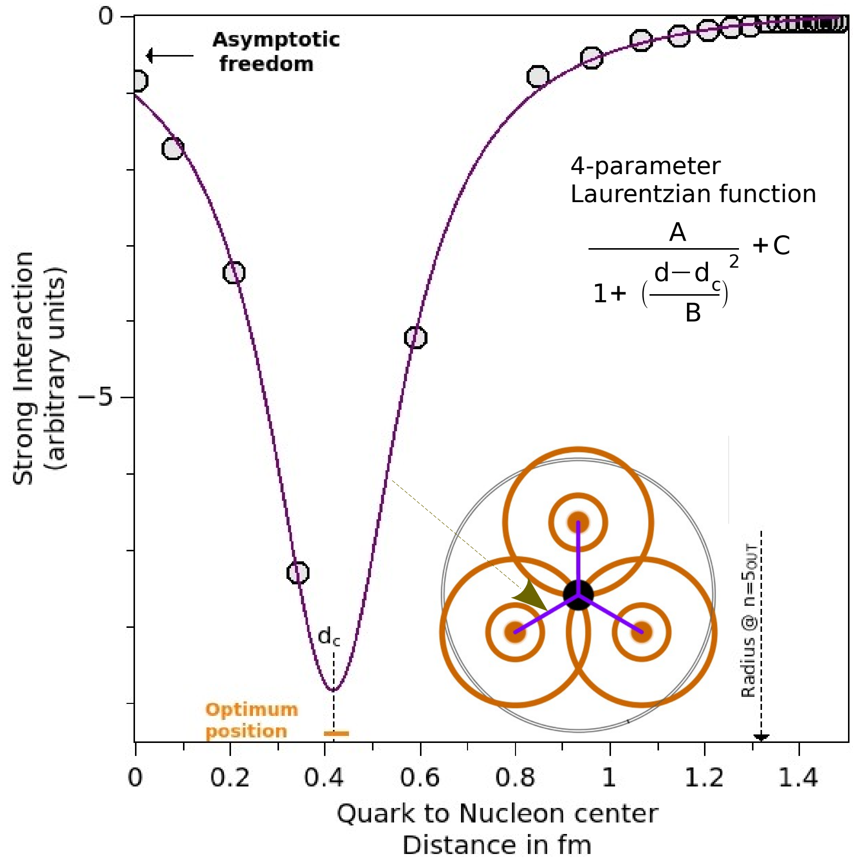


Figure 8: The strong interaction as a function of the distance from the nucleon center

6. Flow chart of the quark substructure genesis

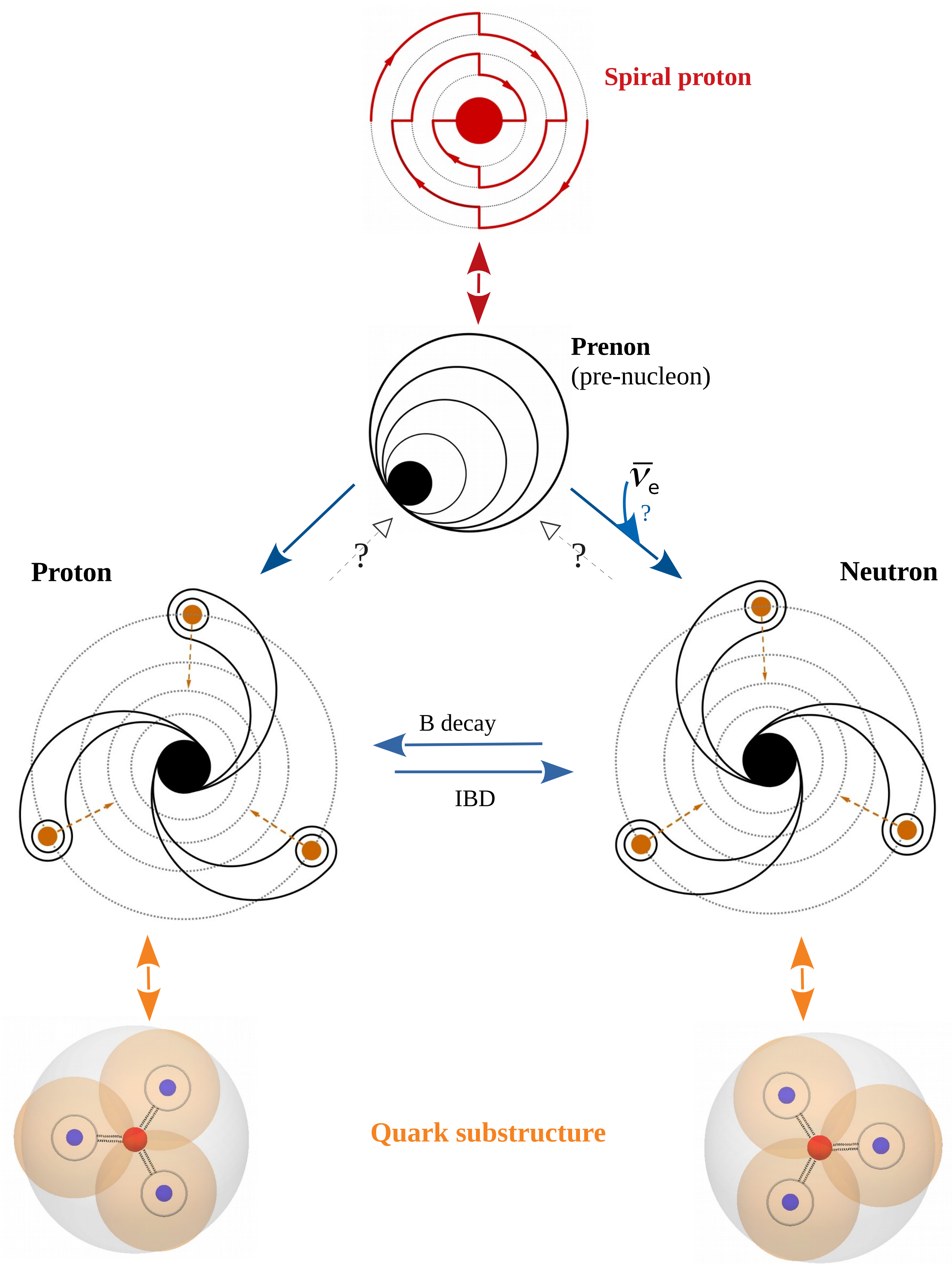
A flow chart summarizing the process leading to the emergence of quark substructure within the nucleon (more specifically the prenon) is presented in Fig.9.

The initial step proceeds from the combination and transformation of two initial linear momenta (m_iv_i + m_jv_j) into angular momenta with centripetal spiral motion. This process, which complies with quantization and conservation rules, must be initiated by a field potential present in the vacuum. The two initial momenta could involve, as an example, a gamma ray and a neutrino. Such a combination would provide a mass-energy equivalent to that of a nucleon.

The prenon resulting from the initial spiraling step must be an intermediate / elusive entity with short lifetime. It leads to the emergence of the quark substructure via a threefold centrifugal spiral process described earlier. Given the fact that the neutron is slightly heavier than the proton, the process leading to the neutron from the prenon could involve an electron antineutrino with high kinetic energy. Originating from the cosmic neutrino background, this e^- antineutrino would compensate for the neutron surplus of mass. It is unknown weather β decay and inverse β decay (IBD) require the intermediate prenon step.

As a result, the composite particle designation for the nucleon remains true, but for differing circumstances. Since quarks stem from the nucleon itself, they are integrated entities and not “foreign particles”, and therefore cannot substantiate the name “composite”. However, the composite attribute may be found in the dual initial momentum producing the spiral proton.

Figure 9: Flow chart of quark substructure genesis - Nature is more subtle than the Big Bang nucleosynthesis theory.



7. The prenon and the EMC effect

There is ample evidence suggesting that the internal configuration of the free nucleon differs from the nucleon bound in nuclei. In the scientific literature, this modification is essentially known as the EMC effect. It was first reported about 37 years ago from deep inelastic scattering (DIS) experiments [10]. Reasons for this modification remain unknown, and despite numerous hypotheses and hundreds of papers published, no consensus has yet been reached.

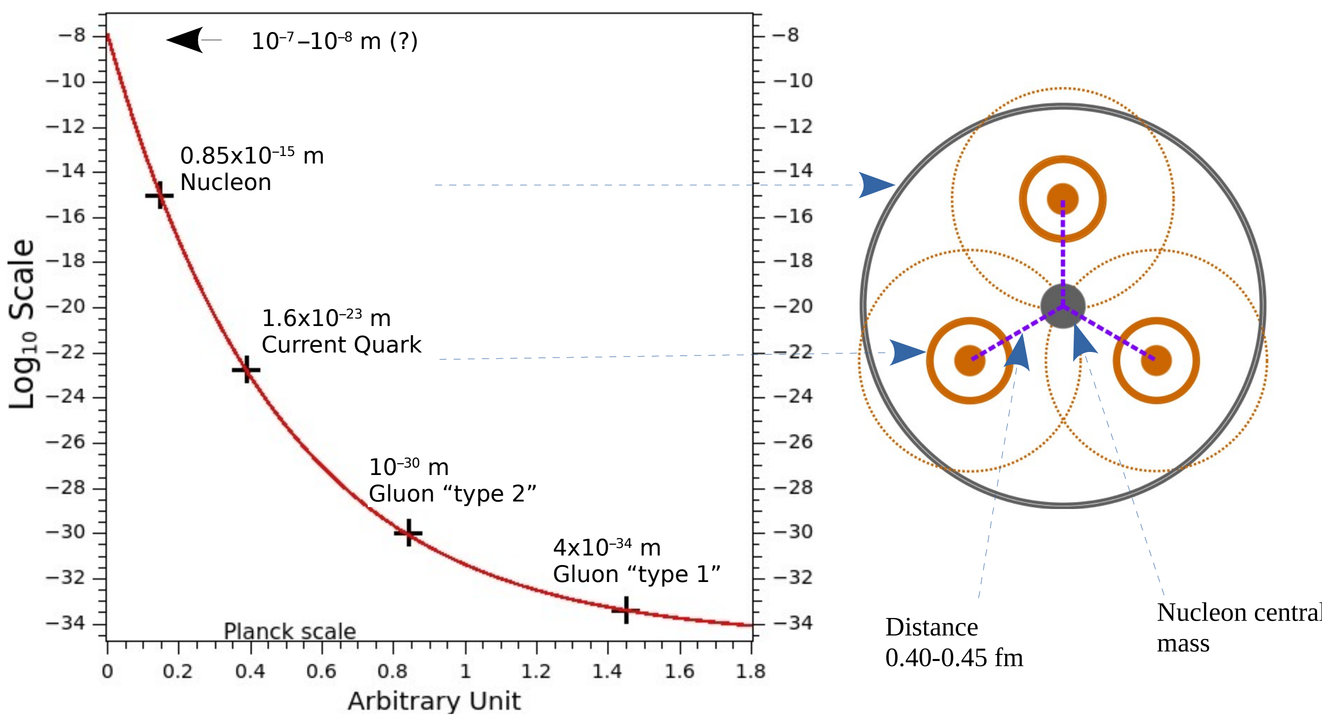
However, if we consider that the free proton exhibits (or may exhibit) the prenon conical spiral structure, then a rational for this modification can be found. The structural difference between the prenon (free proton) vs. the quark substructure (bound proton) would account for the EMC effect. Hence, the quark substructure would be adopted merely for binding purposes and the permutation between the two configurations would be reversible.

8. Scaling within the nucleon

Of paramount interest is the scaling associated with the various components making up the nucleon, explicitly quarks and gluons. Although wrongly associated with attributes such as virtual particles or point particles, quarks and gluons seem to have a definite "size", within the boundary of incertitude principle.

As already specified at [8], quarks are about 10^{-22}–10^{-23} m in size. Gluons are described as dual scale particles, operating at 10^{-30} m (called type 2) and 10^{-33}–10^{-34} m (called type 1). This dual scale could be responsible for the intranuclear force on one hand, and the internuclear force on the other hand.

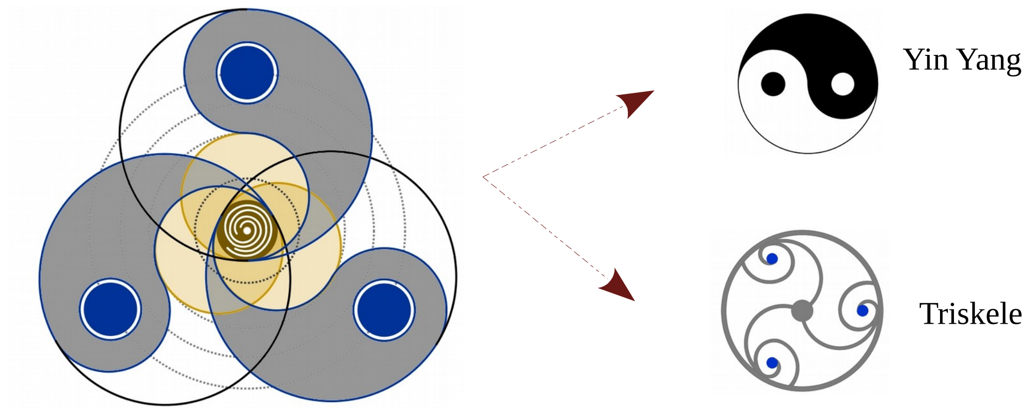
Figure 10: Scaling within the nucleon



9. Demystifying perennial philosophical symbols

Philosophical or mystical symbolism has been part of human life since prehistoric times. The vast majority of these symbols may have a scientific interpretation and a rationale. Here, the successive centripetal and centrifugal spiral processes driving the emergence of quarks within the nucleon, can provide a rationale for some of those everlasting eastern philosophical symbols, in particular the two following symbols known as the Yin Yang and the Triskele (Fig.11).

Figure 11: Illustration of the inward and outward dual spiraling process driving the emergence of quark substructure within the nucleon, as described in the text. The two spirals are symbolized by the blue and white curls. In the central circle where most of the nucleon mass resides, the double inward spiral leading to the spiral proton is outlined. Around the central circle are represented the three quarks. Also depicted are the orbitals followed by the centripetal angular momentum.



10. Conclusion

Gell-Mann persistent intuition about the non-existence of quarks as independent particles was a remarkable achievement, beyond the mathematics of QCD theory he developed from the Lagrangian. The absence of free quarks, and the fact that no independent particle can carry fractional charge, are two considerations that should have motivated our conviction that quarks cannot be self-existent.

Despite the obvious success of the non-pertubative QCD mathematics at formulating the quark theory, the question still remains: how does QCD give rise to the physics of nucleon and constituents? In this regard, a schematic model for the genesis of nucleon/quarks cohesive partnership is propounded.

As we have seen earlier, quarks are merely entities stemming from energy-momentum rearrangement within the nucleon. The objective for this intranuclear transformation can clearly be foreseen: nucleon–nucleon (NN) binding. However, the bewildering consequence is that the very basic building blocks of matter, quarks, are not solid, independent, self-existing particles. Therefore matter (and the whole universe) can neither be regarded as “solid” nor as “self-existing” manifestation. Coincidentally, this is what eastern philosophies have been upholding for centuries.

11. References

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