From 10^{-8} to 10^{-33} m. The interplay of a wide range of scales in the neutron β decay

Bruno R Galeffi

Abstract: The neutron β decay is made possible through the cooperative interplay of an astonishing range of scales, stretching up to 25 orders of magnitude apart. From the size of particles mediating the strong force to the electron antineutrino oscillation wavelength, respective particle scales are reviewed or estimated.

1. Introduction

Outside the nucleus, the neutron has a mean lifetime of ~14 minutes, and then transforms into a proton, an electron, and an electron antineutrino, a process called β decay (Eq.1). There is a discrepancy of about 9 seconds in the actual measurement of neutron lifetime from two different experiments [1]. This discrepancy known as the neutron lifetime puzzle could well be related to the observer effect [2].

After the discovery of the neutron by Chadwick in 1932 [3], more than a decade passed before Snell and Miller first observed the neutron decay [4].

$$n \rightarrow p + e^- + \text{anti-}\nu_e \qquad (1)$$

The neutron β decay is well described by the charged weak current model as a left-handed, purely V–A interaction [5]. Within the Standard Model, neutron decay is viewed more fundamentally as the conversion of a down quark (d) into an up quark (u) through the emission of a virtual W gauge boson[6]. The following equations point to the same process as (1) above, but also include the short-lived W and describe the process on both the nucleon and the quark level:

$$n \rightarrow p + W^- \rightarrow p + e^- + \text{anti-}\nu_e \qquad (2)$$

$$udd \rightarrow uud + W^- \rightarrow uud + e^- + \text{anti-}\nu_e \qquad (3)$$

The reaction $d+\nu_e \leftrightarrow u+e^-$ is fundamental to a host of physical phenomena such as primordial element abundance, solar burning, or neutrino cross sections.

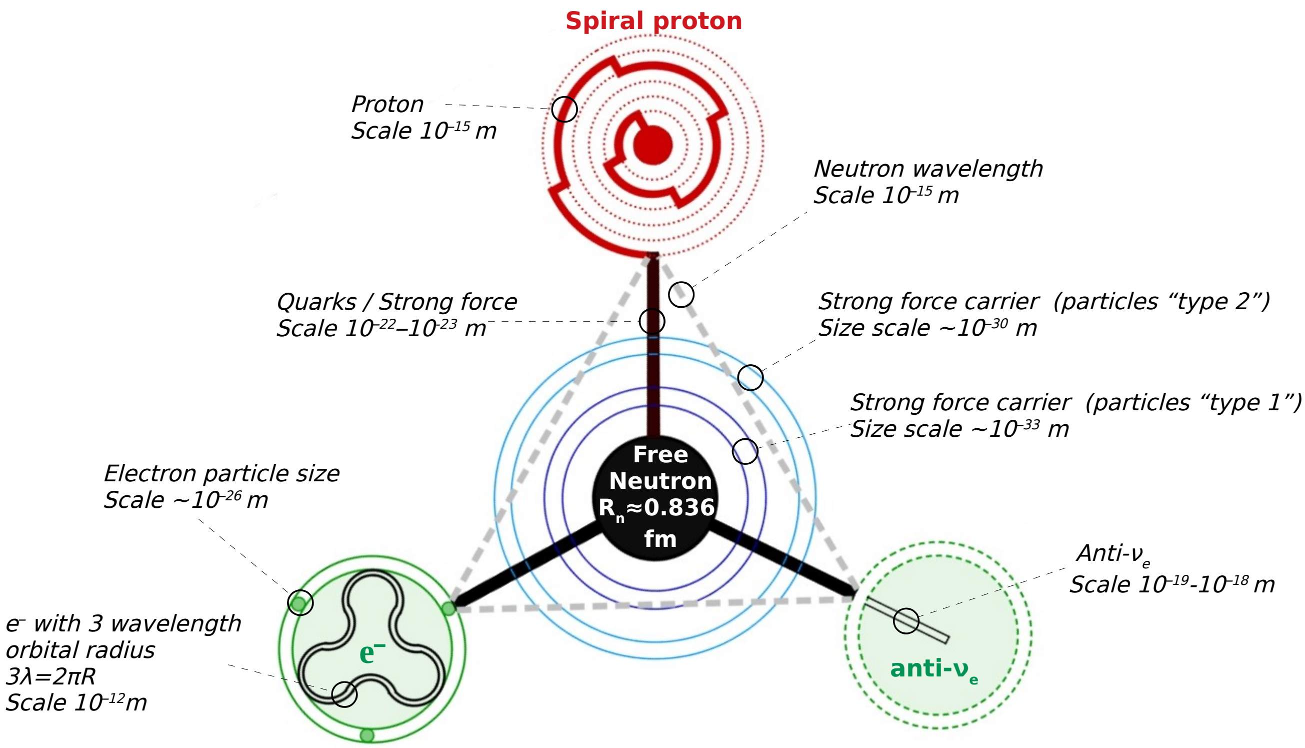
The energy of the neutron is shared among the decay particles, and the kinematics of the decay process is largely driven by the properties of these particles. This energy distribution is astonishing in regards to the permutation of the neutron/quarks/gluons combination into apparently three totally different particles. As the matter of fact, these particles (neutron, proton, quarks, gluons, electron, antineutrino) carry such a huge variety of characteristics like wavelength, mass and particle size that a subtle interplay of all those particles must be acknowledged. Further, this active cooperation must imply some common attributes at the most fundamental level.

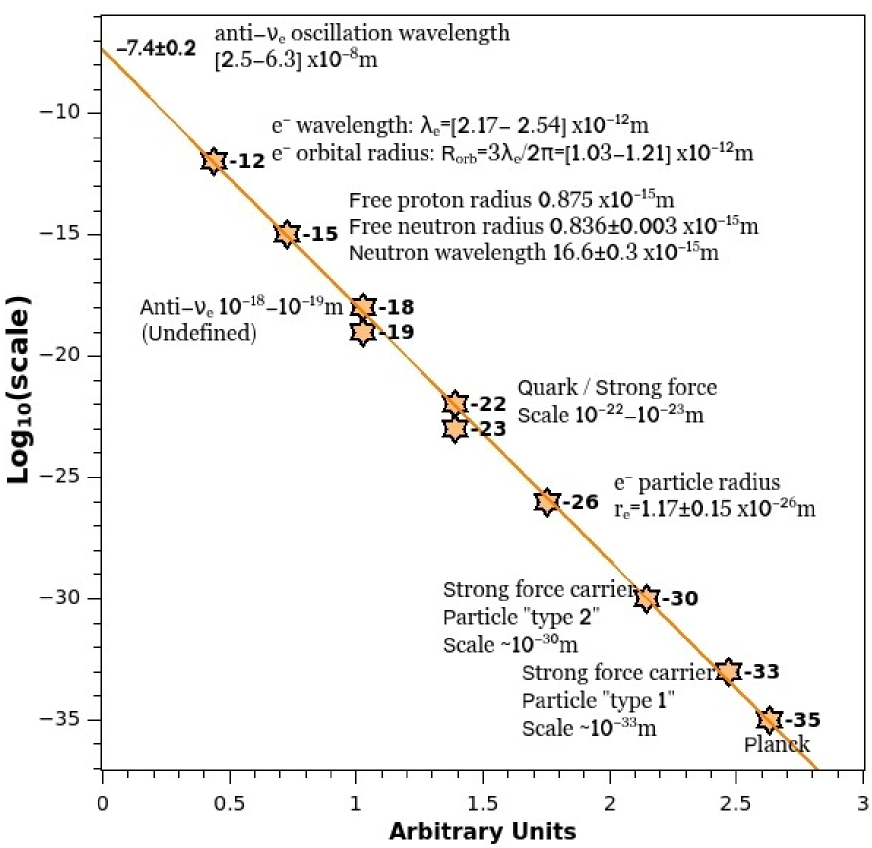
This article outlines some of the intrinsic characteristics of the particles involved in the neutron β decay, in particular with regards to scaling. Some of the data presented are not accessible through experiment due to low sensitivity issues associated with our current instrumentation. They were estimated through analysis and cross-checking of the information from different sources.

2. The neutron β decay schematic diagram

Figure 1 depicts the neutron β decay process, including the three decay particles with connections to the central neutron. In order to align extremely different scales into the same diagram, the $\log_{10}$(scale) is used. Further, the line width (or blank space between two parallel lines with identical colors) is proportional to $-\log_{10}$(scale), so that the smaller the scale the wider the line thickness. This method enables the reproduction of a whole range of scales within the same frame, and the display of smaller scales in great details.

Figure 1 (top): Illustration of the neutron β decay. Scale is graphically represented by the corresponding line width, which is proportional to –log10(scale). Therefore the wider the line the smaller the scale. The line dimension (length) associated with its corresponding thickness (scale) provides the proper value.
Figure 2 (bottom): Graph summarizing the various interacting scales in the neutron β decay





The multiple scales involved in the neutron β decay are conveniently graphed in Fig.2. The smallest scale corresponds to the size of virtual particles called “type 1” mediating the strong force, and this scale is quite close to the Planck scale (~1/100). Is this the closest to the Planck limit physics can go?

3. Neutron radius and wavelength

The free neutron radius proposed above is ~95.5% the size of the free proton (0.836 fm vs 0.875 fm). This neutron radius value is in excellent agreement with the value determined at [7] for the spiral neutron radius (0.834 fm). Within the nucleus, nucleons are “compressed” by a factor estimated between 1.1–1.2.

The neutron wavelength found above (λ_n=16.6 x10^{-15}m) is in good agreement with the energy of a neutron decaying from a neutron-rich isotope [8]. The momentum and energy are given by:

$$p=\frac{h}{\lambda} \approx 4 \times 10^{-20}\,\mathrm{kgms}^{-1} \quad (4)$$

$$E=\sqrt{p^2c^2+m_o^2c^4} = 943.8 \;\mathrm{MeV} \quad (5)$$

The difference from the rest energy of the neutron (939.6 MeV) provides a neutron kinetic energy of ~ 4.2 MeV (~2.2 x10^7 ms^{-1}). This value is typical for neutrons released in nuclear fission [8].

4. The 3-wave electron: orbital radius R_{orb} and particle radius r_e

The e^- seems to describe 3 wavelengths around its own intrinsic orbital. The wavelength value is close to the Compton wavelength calculated for the e^-, which is defined by $\lambda_c = h/m_ec \approx 2.426$ x10^{-12}m. The e^- wavelength λ_e estimated in this study is somewhere between [2.17–2.54] x10^{-12}m, therefore close to λ_c. The intrinsic e^- orbital radius described by the 3 waves is thus given by $R_{orb}= 3\lambda/2\pi=$ [1.03–1.21] x10^{-12}m. The angular momentum $L=mvR_{orb}$ becomes:

$$L=mvR_{orb}=\frac{h}{\lambda_e}R_{orb}=\frac{h}{\lambda_e}\,\frac{3\lambda_e}{2\pi}=3\hbar$$

This value seems to contradict quantum mechanics which restricts L to 1ħ or ħ/2 in Dirac theory.

The orbital of radius R_{orb} described by the e^- should slightly vary with the angular quantum number characterizing its energy level. The electron 3 waves around the orbital R_{orb} and the variable electron radius r_e are depicted in Fig.3. The two scales associated with R_{orb} and r_e are in reality distinct by a factor of ~ 10^{14}.

Figure 3: The electron 3 wavelength and its variable particle radius due to uncertainty principle

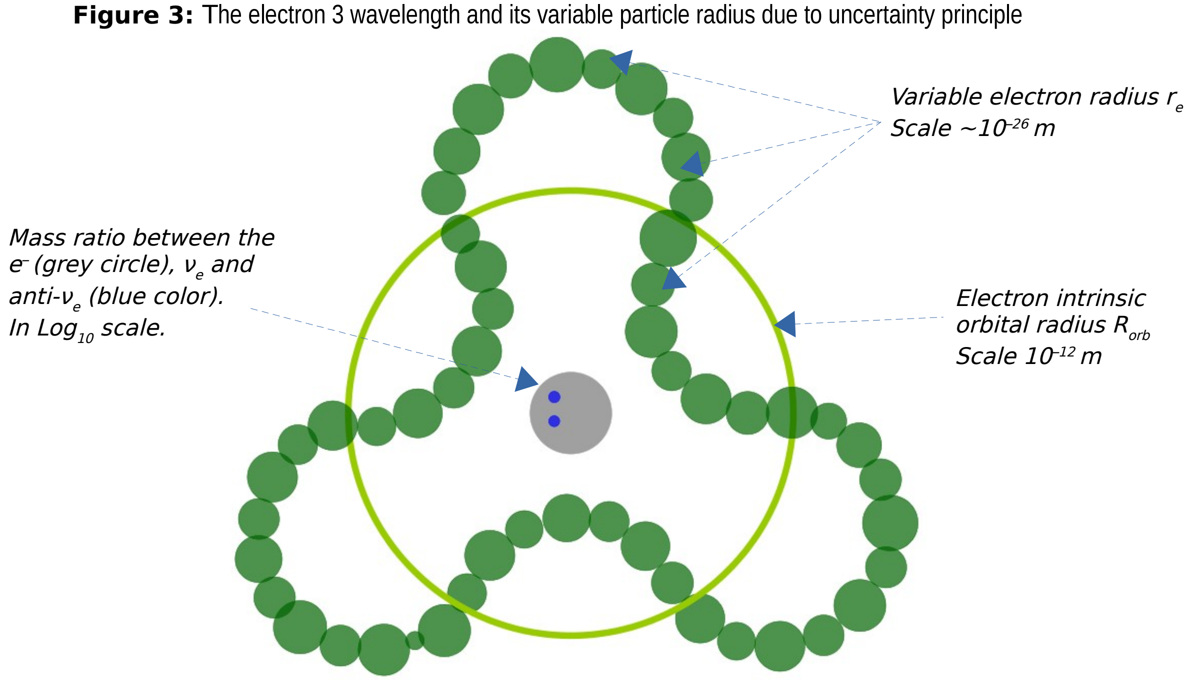
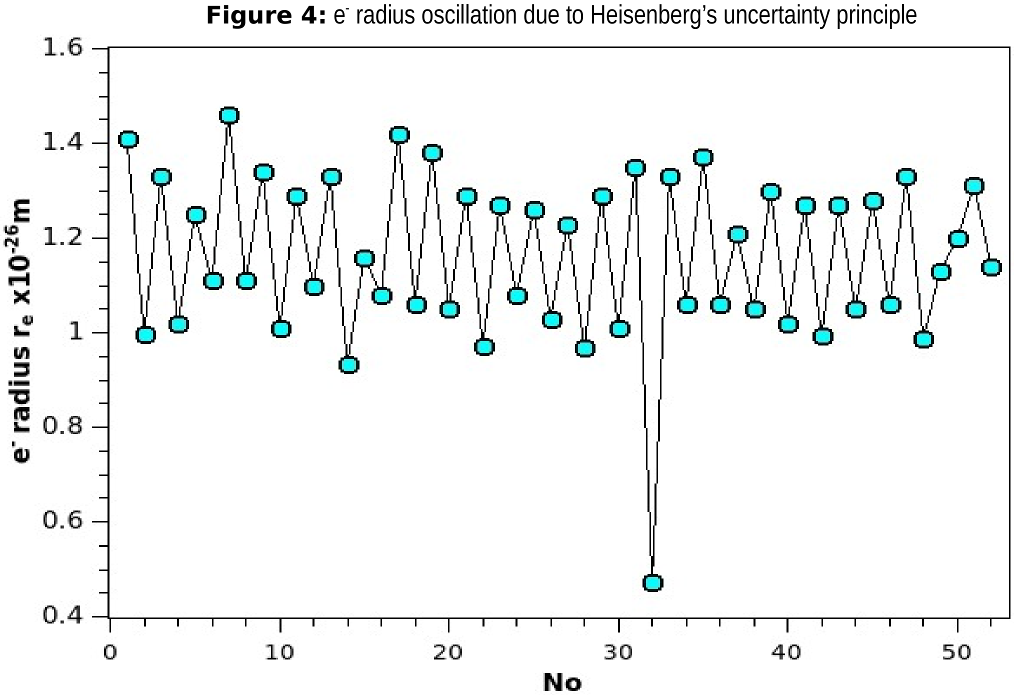


Table 1 presents the electron variable radius data, which is then graphed in Fig.4. A mean radius of 1.17×10^{-26} m with σ=0.15 was determined. The variable radius of the electron is the result of the uncertainty principle. This value for the electron radius is in agreement with the observation of a single electron in a Penning trap experiment suggesting an upper limit of the particle's radius of 10^{-22} m [9].

Table 1: Electron radius data. Number 1 is attributed to the top green sphere in Fig.3.

No	Radius $\times 10^{-26}$ m	No	Radius $\times 10^{-26}$ m	No	Radius $\times 10^{-26}$ m	No	Radius $\times 10^{-26}$ m	No	Radius $\times 10^{-26}$ m	No	Radius $\times 10^{-26}$ m
1	1.41	11	1.29	21	1.29	31	1.35	41	1.27	51	1.31
2	1.00	12	1.1	22	0.97	32	0.47	42	0.99	52	1.14
3	1.33	13	1.33	23	1.27	33	1.33	43	1.27		
4	1.02	14	0.93	24	1.08	34	1.06	44	1.05		
5	1.25	15	1.16	25	1.26	35	1.37	45	1.28		
6	1.11	16	1.08	26	1.03	36	1.06	46	1.06		
7	1.46	17	1.42	27	1.23	37	1.21	47	1.33		
8	1.11	18	1.06	28	0.97	38	1.05	48	0.99		
9	1.34	19	1.38	29	1.29	39	1.3	49	1.13		
10	1.01	20	1.05	30	1.01	40	1.02	50	1.2		

Figure 4: e^- radius oscillation due to Heisenberg's uncertainty principle



5. Electron neutrino: rest mass and oscillation wavelength

A great amount of research is invested in trying to resolve the neutrino puzzle. In particular, the nature of the 3 (more?) flavors and their respective tiny mass values are of paramount interest. Further, evidence of neutrino physics which might break the Standard Model of particle physics is also explored. One other important aspect of neutrino properties, in particular the e^- neutrino, is its possible involvement in carrying consciousness related information [10].

In Fig.3 the ratio of e^- to ν_e rest mass seems to gravitate around 7.1 in Log_{10} base. Therefore the following provides an estimate of the electron neutrino rest mass of ~0.04 eV :

$$\log_{10}(m_e / m_\nu) \approx 7.1 \text{ gives } m_\nu \approx 7.24 \times 10^{-38} \text{ Kg} \approx 0.04 \text{ eV} \qquad (6)$$

Using the e^- antineutrino oscillation wavelength found in Fig.2 ([2.5-6.3] $x10^{-8}$ m), and considering the neutrino velocity ≈ c, the total energy of the e^- antineutrino produced from the neutron β decay is, as expected, mostly kinetic in nature:

$$E_\nu = \frac{hc}{\lambda_\nu} \approx [20-50] \text{ eV} \qquad (7)$$

Further, the maximal energy of the β decay electron has been measured at 0.782 ±0.013 MeV [11]. Given the total energy of the neutron calculated at (5), the energy associated with the proton can therefore be estimated:

$$E_p = 943.8 \text{ MeV} - 0.782 \text{ MeV} - [20\text{-}50] \text{ eV} \approx 943.0 \text{ MeV} \qquad (8)$$

The proton kinetic energy is then $E_{k,p} \approx 4.73$ MeV, which corresponds to a proton velocity of $v_p \approx 3$ x10^7 ms^{-1} or about c/10. (9)

6. The spiral nucleon vs. the nucleon-quark configuration

There is strong 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 and was first reported ~37 years ago from deep inelastic scattering (DIS) experiments [12]. Despite numerous hypotheses and hundreds of papers published, no consensus has yet been reached.

It is believed that the free nucleon exhibits a conical spiral structure, while the quark structure arises through an internal process via rearrangement of the nucleon internal energy. Hence, the quark configuration would be adopted merely for binding purposes. This peculiarity would account for the non existence of free quarks, and the permutation between the two configurations would facilitate the neutron β decay. Quarks scale is estimated between 10^{-22}–10^{-23} m.

The spiral proton was described in length at [7] and [13]. The permutation from spiral to quark configuration would therefore result from a subtle internal energy redistribution, triggered by the proximity of other nucleons or/and neutrinos. Intrinsic properties such as magnetic moment, spin and charge would somehow be preserved from one configuration to the other. Therefore quarks would have no self-existence, merely emerging in the nucleon as a result of internal energy rearrangement for binding requirements. Detailed analysis of the nucleon internal energy rearrangement will be published. Meanwhile, Fig.5 summarizes graphically this concept (page 6).

7. Quantum consciousness scale ?

This article would be lame without alluding to consciousness operating scale, in particular in regards to the possible involvement of the electron neutrino in carrying consciousness information. To the great discomfort of many physicists, the mind forced its way early into quantum theory through the "double-slit experiment" [14] and it would not go away.

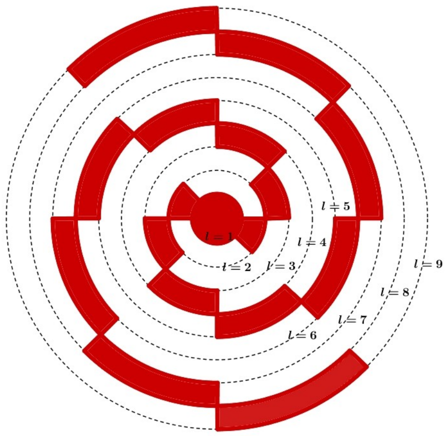
Today, it is rather difficult to avoid the implication that consciousness and quantum mechanics are somehow linked. This idea was hypothesized by Roger Penrose already in the 1980's. There is undeniable evidence suggesting that consciousness operates at the quantum scale, at least in some of its manifestations.

Thus one can ask what is the quantum scale at which consciousness operates. Could it be the Planck scale, higher or lower? Should it be smaller than the smallest particle in the universe? As seen earlier, some of the particles mediating the strong force operate at the 10^{-33} m scale, and a particle scale even lower could be found for neutrinos. The answer will provide a great advancement for physics.

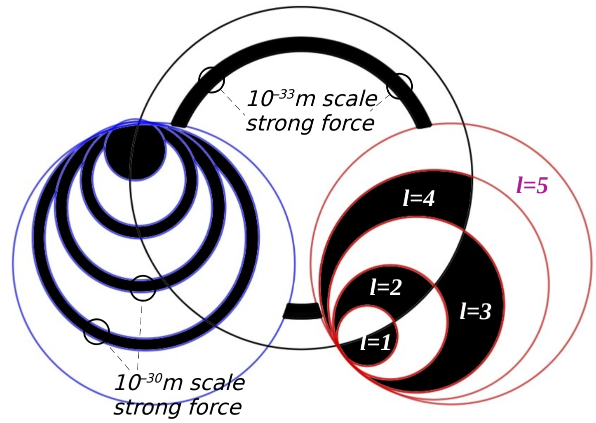
Just like sand particles flowing across the hourglass, so are invisible consciousness particles flowing across the universe.

Figure 5 (next page): Schematic of the equilibrium between the free nucleon in a spiral configuration and the bound nucleon in a quark configuration. The configuration permutation is the result of internal energy rearrangement for binding purposes. Therefore quarks might have no self-existence.

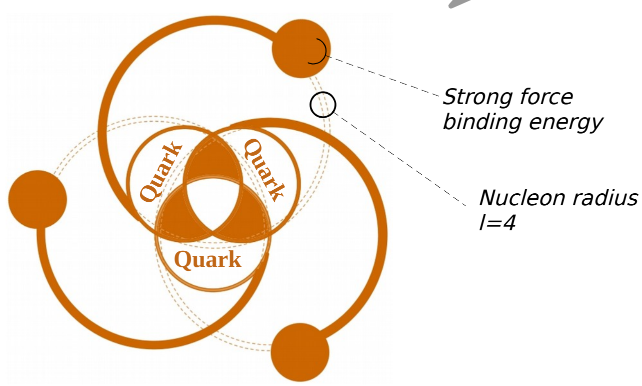
Generation of the nucleon double spiral through angular momentum acquisition and spiral motion [7], [12]. Angular momentum quantum numbers are shown from from l=1–9, with l=1–4 being foremost.



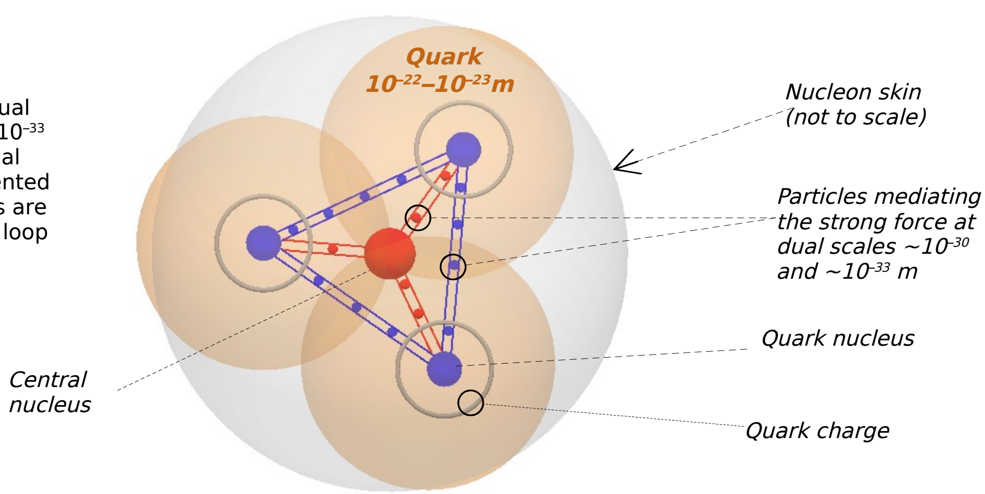
The ½ spins spiral nucleons, with opposed spins for proton and neutron. The dual scale strong force is indicated as arising for the nucleon internal structure.



The strong force and the 3 bound quarks are depicted stemming from the nucleon itself through internal energy rearrangement.



Three quarks bound via the dual strong force scaled 10^{-30} and 10^{-33} m. Particles mediating this dual scale strong force are represented with 2 different colors. Quarks are shown here with nuclei and a loop depicting the electric charge



7. References

[1] *For a recent article, see for example: "A new study of the EMC Effect using the Fn2 neutron structure function" H. Szumila-Vance, C. Keppel, S. Escalante, N. Kalantarians; https://arxiv.org/abs/2002.02597 . Also Wikipedia: "Free neutron decay" online*

[2] *"Consciousness and the double-slit interference pattern: Six experiments" D. Radin, L. Michel, K. Galdamez, P. Wendland, R. Rickenbach, and A. Delorme; Physics Essays 25, 2 (2012). Also Wikipedia: "Observer effect (Physics)" online*

[3] *F. Chadwick 1932 Proc. R. Soc. Lond. A 136 692*

[4] *A. Snell and L. Miller 1948 Phys. Rev. 74 1217A*

[5] *J.S. Nico; "Neutron beta decay"; J. Phys. G: Nucl. Part. Phys. 36 (2009) 104001 (36pp) and Ref therein*

[6] *Wikipedia: "Beta decay" online*

[7] *B.R Galeffi; "Angular Momentum Acquisition and Spiral Motion, a Requisite for Particle Creation. A Case Study, the Proton"; ViXra:1809.0594 online*

[8] *Wikipedia: "Neutron temperature" online*

[9] *Hans Dehmelt; "A Single Atomic Particle Forever Floating at Rest in Free Space: New Value for Electron Radius"; Physica Scripta, Vol 1988, T22, 102-110*

[10] *M. Goodman; "A Physical Biology, the Electron Neutrino Mass, and the Role of Quantum Mechanics in Nature"; NeuroQuantology | November 2018 | Volume 16 | Issue 11 | Page 49-54 | and Ref therein*

[11] *Wikipedia: "Free neutron decay" online*

[12] *For a recent review (2017) see: O. Hen, G.A. Miller, E. Piasetzky, L.B. Weinstein; "Nucleon-Nucleon Correlations, Short-lived Excitations, and the Quarks Within" https://arxiv.org/abs/1611.09748*

[13] *B.R. Galeffi; "The Spiral Proton by Numbers: Composite Angular Momentum, Mass Discrimination, and G-Factor as 1"; viXra:1901.0089 online*

[14] *D. Radin, L. Michel, K. Galdamez, P. Wendland, R. Rickenbach, A. Delorme; "Consciousness and the double-slit interference pattern: Six experiments"; Physics Essays 25, 2 (2012)*