

Electron Pairs and the QCD $u\tilde{d}\tilde{d}\tilde{u}$ Tetrahedrons

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Abstract: We propose that the QCD exotic meson tetraquarks $u\tilde{d}\tilde{d}\tilde{u}$ introduced in previous papers may be condensed pions, a meson-meson bound state having a tetrahedron structure. We note that the QFT quantum harmonic oscillator zero-level does not describe well the non-empty ground state and that the QCD tetrahedrons that fill space may be a better description for the QFT ground state. We assume that electrons and positrons are composite particle charged mesons, $d\tilde{u}$ for the electrons and $u\tilde{d}$ for the positrons that spin around their center of mass. We propose that the QCD tetrahedrons play a central role in the electron pairing mechanism in both molecules and superconductors. We suggest that the cosmological redshift may be alternatively, or in addition to, due to the QCD tetrahedron density variations in space and particularly due to its density reduction in the cosmic web great voids.

Keywords: QCD Gas, Tetrahedrons, Cooper Pairs, Isotope Effect, Superconductor, Dirac Equation, Klein paradox, Cosmic Web Voids, Doppler Redshift, Black Holes, AGNs.

1. Electrons, Positrons and the QCD Tetrahedrons

Inspired by the Loop Quantum Gravity (LQG) tetrahedrons¹ we propose that the QCD exotic meson tetraquarks $u\bar{d}d\bar{u}$ introduced in previous papers^{2,3,4,5} may have tetrahedron structure as illustrated below. We also note that pion π^0 is comprised of the same four quarks and antiquarks of the exotic meson $u\bar{d}d\bar{u}$

$$d\bar{d} + u\bar{u} (\pi^0) \rightarrow u\bar{d}d\bar{u} (\text{tetrahedron}) \quad (1)$$

The pion tetrahedrons are assumed to have about two order of magnitudes smaller volume comparing to protons and that they fill space and are compressible and responsive to charges and fields. The pion tetrahedrons may be deformed and polarized into two orthogonal planes where the deformed tetraquarks are positioned in the XY or the YZ planes.

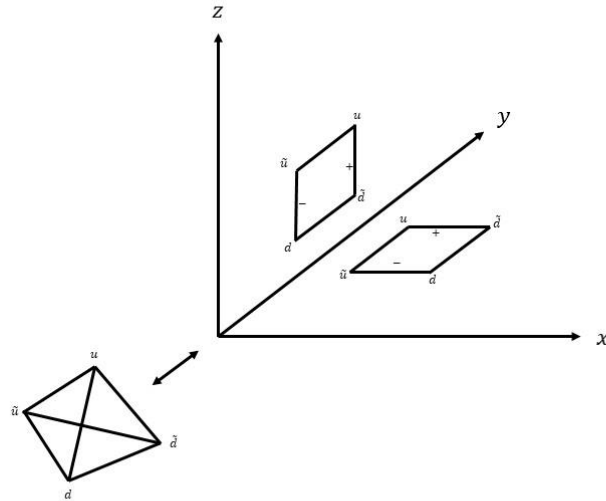


Figure 1 illustrates the proposed QCD pion tetrahedrons and its two planar orthogonal polarizations where the tetraquarks are positioned in the XY or the YZ planes

In a previous paper we suggested that the compact exotic meson tetraquarks may be peculiar positroniums (see further below Crater and Wong TBDE solution)^{6,7}. We further propose here that the $u\tilde{d}$ meson plays the positron part and the $d\tilde{u}$ meson plays the electron part of the condensed peculiar positronium. Accordingly, we assume that electrons and positrons are composite particles that spin around their center of mass and polarize their surrounding QCD tetrahedrons according to their spin state.

Dirac's Hamiltonian spin-orbit operator couples the momentum of the electron and the positron spinor, hence, matter and antimatter components are mixed by the Dirac Hamiltonian and cannot be separated⁸. The exchange of an electron with a virtual electron-positron pair described by a Feynman diagram⁹ may be a fundamental process that mix matter and antimatter quarks and antiquarks as described by the exchange reaction equation -

$$d\tilde{u}_{(e^1)} + [u\tilde{d}_{(p)} d\tilde{u}_{(e^2)}]_{tetraquark} \rightarrow [d\tilde{u}_{(e^1)} u\tilde{d}_{(p)}]_{tetraquark} + d\tilde{u}_{(e^2)} \quad (2)$$

It should be noted that according to equation 2 electrons are not created nor destroyed from the vacuum state like assumed by QFT, the electrons exchange their positron partners.

Studying the Dirac equation, Klein found that electrons can cross a potential barrier without the exponential damping expected from non-relativistic quantum tunneling¹⁰. Brito wrote that the creation of particle-antiparticle pairs at the potential barrier explains the undamped transmitted part solving the Klein paradox¹¹. The solution of Klein paradox suggests that nucleus take part in electron pairing dynamics by exciting electron-positron pairs.

The fine and hyperfine structure of the hydrogen atom energy levels can be derived from Dirac equation¹². The magnetic hyperfine spin-spin interaction is attractive and singular at short distances-

$$W_{\text{hyperfine}} = -\frac{8\pi}{3} \mu_e \cdot \mu_p \delta(R) \quad (3)$$

The positron magnetic moment is about 2000 times bigger than the proton magnetic moment μ_p and hence the hydrogen atom fine and hyperfine perturbative solution is not justified for the positronium system. Crater and Wong solved the Two Body Dirac Equation (TBDE) system with the constraint dynamics approximation and found a new ground state significantly more strongly binding than the more familiar positronium solution of about 6.8 eV. The condensed peculiar positronium binding energy is about 300 KeV and its bond length is three orders of magnitude shorter than the hydrogen atom bond length. The main attraction term in Crater and Wong TBDE approximate solution is the magnetic spin-spin attraction term of equation 3. The peculiar positronium existence and its expected decay via 4 photons were not experimentally verified yet and a non-radiative decay channel to the QCD ground state may exist that compete with the radiative channel.

In the next section we propose that the QCD tetraquarks take part in electron pairing in molecule chemical bonds.

2. Electron Pairing in Molecules and the QCD Tetrahedrons

Herzberg studied the dissociation energies of the hydrogen molecule (H_2) and its isotopes HD and deuterium (D_2) molecules¹³. The dissociation energies in the ground electronic state of the three molecule isotopes are 36,118.3 cm^{-1} , 36,406.2 cm^{-1} and 36,748.9 cm^{-1} . The heavier isotopes HD and D_2 have bigger dissociation energy than the hydrogen molecule. The non-adiabatic corrections to rovibrational levels of the hydrogen molecule was studied by Puchalski and Komasa that concluded that the non-adiabatic corrections adds to the moving ions an electron coat that changes the effective mass carried by the ions¹⁴. Puchalski et al studied the relativistic corrections for the ground electronic state of molecular hydrogen

and concluded that the ions relativistic recoil corrections might be larger than previously anticipated¹⁵. The outcome of the isotope effect in molecules is different from the isotope effect in superconductors but their source is similar. In both cases the isotope effect couples the ions to the electrons motion affecting the electron pairing mechanism.

The polarized QCD tetraquarks, $u\tilde{d}\tilde{d}\tilde{u}$, may create an effective attractive force between electrons for example in the hydrogen molecule. The QCD tetraquarks polarization created by two electrons with opposite spins is parallel in the center between the two ions creating an effective attraction between the electron pair and the two hydrogen ions.

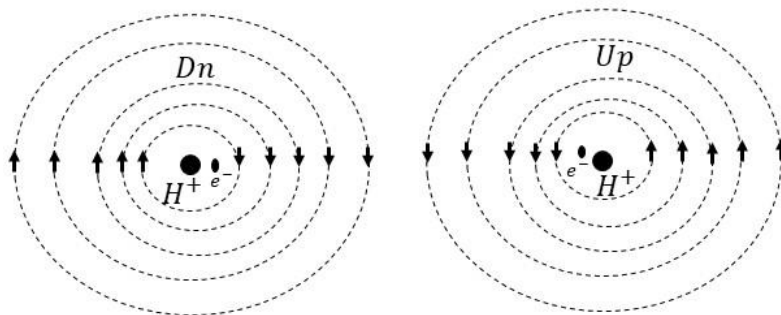


Figure 2 illustrates the QCD tetraquarks polarization due to pair of electrons with opposite spins in a Hydrogen molecule.

A coherent double exchange reactions with two electron-positron pairs as described in equation 2 above may occur for example at the elliptic turning point as shown below. A first electron-positron pair may pop up on the right-side hydrogen ion, the positron creates a peculiar positronium tetraquark tetrahedron with the first electron in the ion center and the second electron is released at the elliptic turning point. Same sequence of events may occur coherently at the left-hand side hydrogen ion. The double exchange reactions may occur coherently and the electrons of the two ions exchange of ions form a chemical bond between the two ions.

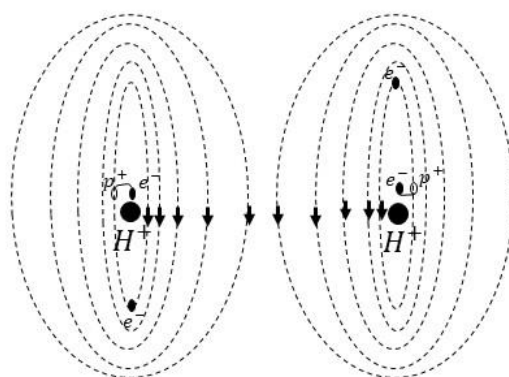


Figure 3 illustrates the QCD tetrahedron elliptic polarization creating an effective attraction between the electron pairs and a chemical bond between the two ions.

The Feynman diagram below illustrates the coherent double exchange reactions of two electrons with two electron-positron pairs excited by the two ions forming a chemical bond. The

double exchange reactions lower the repulsive Coulomb interaction between the two electrons and the overall result is a force created between the two ions that forms the chemical bond.

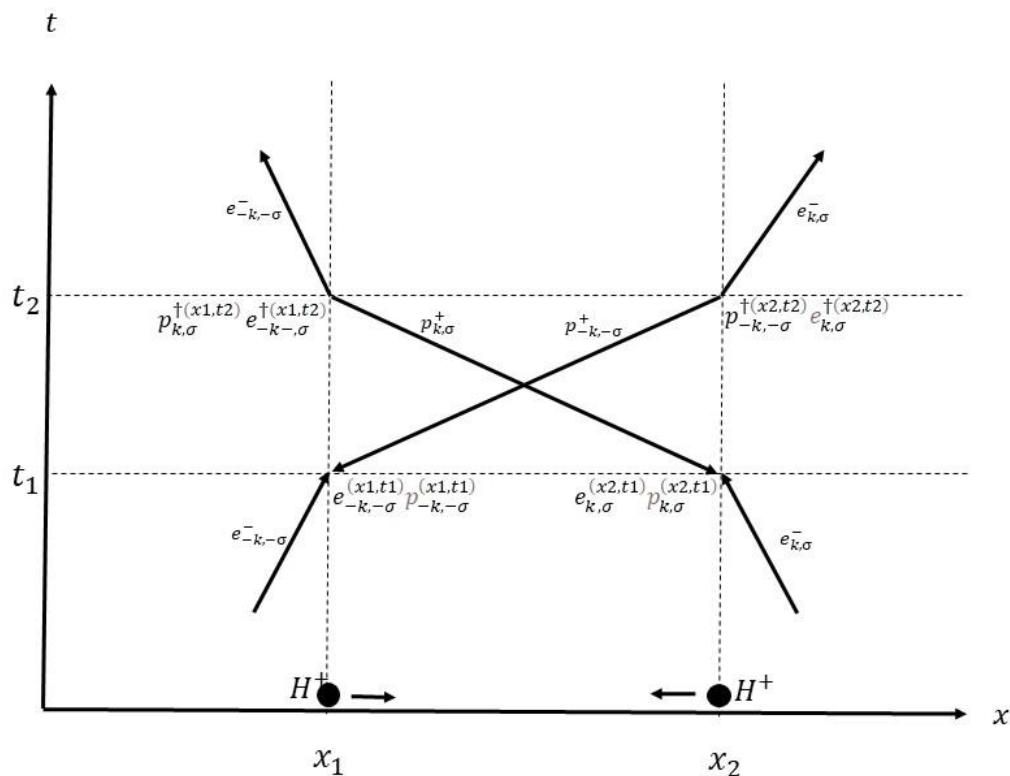


Figure 4 illustrates with a Feynman diagram the coherent double exchange reactions of two electrons with opposite spins with two electron-positron pairs tetrahedrons excited by the two hydrogen ions.

The spin polarization effect described above by the double exchange reaction of two electrons may be analogous to the Casimir force between two neutral plates in the vacuum. If a quantum system is confined between walls (here by the two ions) the ground state energy reduction will lead to a net force between the walls¹⁶.

The isotope effect in the dissociation energy of the hydrogen, HD and deuterium molecules may be similar to the superconductor isotope effect described below¹⁷ hinting that the electron pairing mechanism in both cases has a similar source.

In the next section we show that the QCD tetraquarks may create a cosmological redshift alternative or in addition to the Doppler redshift.

3. Redshift and the QCD Tetrahedrons

Gray and Dunning-Davies reviewed the interpretation of redshift in cosmology and astrophysics, discussed the history and origin of the traditional accepted idea of Doppler redshift and described other possible mechanisms for the redshift¹⁸. For example, the tired light theory was first proposed in 1929 by Fritz Zwicky, who suggested that photons lose energy over time via interaction with matter or by some other novel physical mechanism¹⁹. Gray and Dunning-Davies noted that the Doppler and/or space-expansion effects will yield similar photon and neutrino redshifts, whereas a non-Doppler mechanism arising from an energy-loss interaction with intervening matter will result in different redshifts for the two cases²⁰.

In previous paper we assumed that the QCD tetraquarks density vary in space according to the gravitational field like earth's atmospheric density². The cosmic web is built from filaments of galactic walls and great voids. We suggest that the light that travels from far away galaxies and reach for example the Webb telescope pass some of these great voids where the QCD gas density is low causing the redshift. Light that comes from galaxies that are farther away cross more great voids on their path and accumulate more redshift proportional to their distance. The combination of the QCD tetraquarks density variations in space and the cosmic web great voids may be an alternative mechanism for the cosmological redshift that depends on their distance.

4. Electron Pairing in Superconductors and the QCD Tetrahedrons

The Superconductor electron pairing mechanism forming Cooper pairs²¹, especially in the high temperature superconductors (HTSC) is not fully understood. The Bardeen-Cooper-

Schrieffer (BCS) theory²² assumes that the interaction between electrons becomes attractive and dominates the repulsive Coulomb interaction in the vicinity of the Fermi energy level. The ground state of a superconductor, formed by electrons virtually excited in pairs of opposite spin and momentum, is assumed to be lower in energy than the normal ground state. BCS noted that the discovery of the isotope effect^{23,24} was a breakthrough that indicated that electron-phonon interactions are primarily responsible for superconductivity. According to BCS theory due to the isotope effect, $T_c \sqrt{M}$ is expected to be a constant, where T_c is the superconductor phase transition temperature and M is the lattice ions mass. The superconductor isotope effect proves that the lattice ions motion plays dynamic part in the electron pairing mechanism. Eliashberg included time-dependent phonons dynamics to the electron pairing mechanism²⁵.

In previous papers, we suggested that quark and antiquark pair exchange reactions between particles and the QCD tetraquarks similar to equation 2 above may accelerate or decelerate particles and that the quarks and antiquarks numbers are strictly conserved. We suggested that antimatter plays a principal role in the universe and is inseparable from both matter, via Dirac' spinors, and space, via the quarks and antiquarks pair exchange reactions with the QCD tetraquarks^{2,3,4,5}. In this paper we propose that the QCD gas plays a role in the electron pairing mechanism in both molecules and superconductors. We suggest that the electron spins polarize the QCD tetrahedrons and that ions motion in both molecules and superconductors create coherent electron-positron excitations and double electron exchange reaction with the QCD tetrahedrons according to equation 2 and figure 4 above (with heavier ions of superconductors replacing the hydrogen ions) that reduce the system energy in the vicinity of the Fermi energy and create the collapse to the lower energy superconducting ground state^{21,22}. The effects of the electron pairing in molecules and superconductors are different, in molecules electron pairs with

opposite spins create chemical bonds and in superconductors the electron pairs enable the collapse to the lower energy superconducting state, however, the underlying electron pairing mechanism may be similar involving ions motion that creates electron-positron pair excitations from the QCD tetraquarks tetrahedrons.

5. Quantum Field Theory (QFT) and the Non-Empty Ground State

QFT solved the long-standing problem of Dirac negative energy states. QFT creation and destruction operators create and destroy both particles and antiparticles and both have positive energies²⁶. QFT introduces extremely elegant mathematics, however, it seems not to describe well the non-empty physical ground state, the quantum vacuum, using the free fields operators of the quantum harmonic oscillator²⁷.

The quantum harmonic oscillator model assumes that a harmonic potential in space exists of the general form $V(q) = \frac{1}{2}m\omega^2q^2$ and the result is the harmonic oscillator bound state spectrum $H|n\rangle = \left(n + \frac{1}{2}\right)\hbar\omega|n\rangle$. Accordingly, the zero-level empty state of the harmonic oscillator is $E_0 = \frac{1}{2}\hbar\omega$, however, free electrons and protons (comprised of quarks) are stable and do not decay to a lower zero-level empty ground state. There is no physical process that takes stable particles and destroy them to an empty lower energy ground state.

The creation and destruction operator of the quantum harmonic oscillator model raises or reduces the Hamiltonian energy as follows:

$$H a^\dagger |n\rangle = (E + \omega)|n\rangle \quad (4a)$$

$$H a |n\rangle = (E - \omega)|n\rangle \quad (4b)$$

$$H a |0\rangle = 0 \quad (5)$$

However, equations 4a-b and particularly 5 do not describe complete physical processes. The physical processes described by Feynman diagrams destroy for example a particle and an antiparticle in a vertex, but a high energy photon is created. Particles may be transformed to other particles in QFT but an empty physical state cannot be produced by any physical process that must conserve total momentum, energy, charge, spin, QCD color etc.

Rugh and Zinkernagel noted in their review on the quantum vacuum and the cosmological constant problem that the pion π^0 mass is proportional to its expectation value in the QCD ground state quark condensate, which does non-vanish²⁸

$$\langle 0|\pi^0|0\rangle = \langle 0|d\tilde{d} + u\tilde{u}|0\rangle \quad (6)$$

We propose that a better candidate for the physical ground state may be the QCD tetrahedrons in a meson-meson bound state phase. QCD bound states are reviewed by Hoyer²⁹ and by Fariada-Veiga and O'Carroll that reviewed meson-meson bound state using a Lattice QCD model³⁰. A meson-meson bound state was found below the two-particle threshold and two sources of the meson-meson attraction were pointed out. A quark-antiquark exchange referred to as a quasi-meson exchange and a gauge field correlation of four overlapping bonds, two positively oriented and two of opposite orientation. Fariada-Veiga and O'Carroll noted that the main mechanism for the formation of the meson-meson bound state comes from the gauge contribution. QCD at finite temperature and chemical potential has a rich phase structure³¹. Dense QCD has both chiral and diquark condensates with a cross over between the broken chiral symmetry and color superconducting phase³².

The hypothesis proposed in this and previous papers^{2,3,4,5} is:

1. No empty vacuum ground state exists - there is no physical process that destroy particles to null or creates particles from null. Stable particles do not decay and the ground state is not empty.
2. Matter and antimatter symmetry - there must be equal number of matter and antimatter particles in the universe, the missing antimatter particles are hidden probably under the event horizon of black holes.
3. The fundamental matter and antimatter particles are: u, d, \bar{d} and \bar{u} quarks and antiquarks.
4. QCD tetrahedrons comprised of $u\bar{d}d\bar{u}$ pions fill space.
5. Electrons and positrons are composite particles, $d\bar{u}$ is the electron, $u\bar{d}$ is the positron. Protons and neutrons are made of three quarks, proton is uud and the neutron is udd . Unstable transition state particles are comprised of various combinations of the fundamental quarks and antiquarks.
6. The electron pairing mechanism in atoms and molecules forming chemical bonds and in superconductors forming Cooper pairs and the collapse to the superconducting state is enabled by the QCD tetrahedrons polarization and coherent exchange reactions of electron pairs with the QCD tetrahedrons electron-positron pair excitations.
7. Active AGNs act as matter reactors²⁴ that increase the density of the QCD tetrahedrons in space by duplicating the $u\bar{d}d\bar{u}$ pions in their ergoregion laser cavities³³.

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