Stable Tetraquarks

Physicists peering inside the neutron are seeing glimmers of what appears to be an impossible situation. The vexing findings pertain to quarks, which are the main components of neutrons and protons. The quarks, in essence, spin like tops, as do the neutrons and protons themselves.

Now, experimenters at the Thomas Jefferson National Accelerator Facility in Newport News, Va., have found hints that a single quark can briefly hog most of the energy residing in a neutron, yet spin in the direction opposite to that of the neutron itself, says Science News. [10]

The puzzle comes from experiments that aimed to determine how quarks, the building blocks of the proton, are arranged inside that particle. That information is locked inside a quantity that scientists refer to as the proton's electric form factor. The electric form factor describes the spatial distribution of the quarks inside the proton by mapping the charge that the quarks carry.
[9]

Taking into account the Planck Distribution Law of the electromagnetic oscillators, we can explain the electron/proton mass rate and the Weak and Strong Interactions. Lattice QCD gives the same results as the diffraction patterns of the electromagnetic oscillators, explaining the color confinement and the asymptotic freedom of the Strong Interactions.

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Preface

The diffraction patterns of the electromagnetic oscillators give the explanation of the Electroweak and Electro-Strong interactions. [2] Lattice QCD gives the same results as the diffraction patterns which explain the color confinement and the asymptotic freedom.

The hadronization is the diffraction pattern of the baryons giving the jet of the color – neutral particles!

Theorists identify stable tetraquark

Two independent groups of theorists have shown for the first time that exotic particles made up of four quarks can exist for extended periods of time. Using different approaches, the researchers predict the existence of a stable "tetraquark" containing two heavy (bottom) quarks and two light antiquarks. They say that the particle could be detected in a few years' time at the LHCb experiment on the Large Hadron Collider at CERN.

Quarks were proposed by Murray Gell-Mann and George Zweig in 1964 as the fundamental building blocks of protons, neutrons and other baryons, which contain three quarks, and mesons, made up of a quark and an antiquark. Since then physicists have also studied the possibility of more exotic composites, including tetraquarks, composed of two quarks and two antiquarks, and pentaquarks, which comprise four quarks and an antiquark.

A number of particles resembling tetraquarks have been observed at colliders over the past decade or so, such as the X(3872) particle first detected by the Belle experiment in Japan in 2003. More recently in 2016, the discovery of a tetraquark was claimed by physicists working at Fermilab. However, researchers working at LHCb were not able to confirm the Fermilab result.

Chris Quigg of Fermilab says that no definitive discovery has yet been made because it has never been entirely clear whether the detected particle debris – taken to be the components of tetraquarks – are created together or separately in the collisions. “In the case of tetraquarks, people can always put forward alternative explanations,” he says.

Heavy and light

Now, Quigg and his Fermilab colleague Estia Eichten on the one hand, and Marek Karliner of Tel Aviv University together with Jonathan Rosner of the University of Chicago on the other, say they have proved the existence of a tetraquark made from two of the heaviest quarks (bottom quarks) – and the two lightest antiquarks, an antiup and an antidown. The quark notation for the particle is bbu d.

Karliner and Rosner rely more heavily on experimental data in their analysis, particularly those from the discovery at LHCb in July of the Ξ^{++}_{cc} particle, which consists of two (heavy) charm quarks and an up quark. The pair had predicted back in 2014 that Ξ^{++}_{cc} should have a relatively low mass owing to the charm quarks attracting each other very strongly and thereby lowering their binding energy. In fact, the researchers reckoned that the charms’ binding energy ought to be half that of a charm-anticharm pair in mesons such as the J/psi particle.

Their reasoning was vindicated when the observed mass of Ξ^{++}_{cc} – 3621 +/-1 MeV/C^2 – turned out to match the predicted value – 3627 +/-12 MeV/C^2. In the latest work, they extrapolate their approach to a system containing two bottom quarks, rather than two charm quarks, and posit that the binding energy of the bb pair in bbu d is half that of a b b pair, which, they say, is well known from the masses of mesons such as the upsilon. By then incorporating the known mass of a u d, they work out that the tetraquark ought to weigh in at 10389 MeV/C^2, give or take 12 MeV/C^2.

Very stable

The researchers point out that this value is significantly lower – by some 215 MeV/C^2 – than that of the lightest combination of known baryons and mesons with the correct properties. As such, they say, this tetraquark will be stable under the strong interaction, the force that holds protons and neutrons together. It will instead only decay via the weak interaction, for which typical decay times – a relative eternity at 10^{-13} s – are about ten orders of magnitude longer than that of the strong interaction. “This hadron is as stable as ordinary baryons and mesons that only decay through the weak interaction,” says Karliner.

Quigg and Eichten reach a similar conclusion but starting from first principles. They consider an idealised case in which two infinitely heavy quarks combine with two light antiquarks, and they find that the resulting particle should be stable and only decay via the weak interaction. Such a particle, says Quigg, can be thought of as a helium nucleus – the (very small) pair of quarks – with two electrons orbiting it.

To apply their finding to the real world, the pair then made “controlled approximations” in which they substituted the infinitely heavy quarks with ones having a large but finite mass. Relying (in the absence of the necessary experimental data) on Karliner and Rosner’s calculation of doubly heavy baryon masses, they calculated the properties of specific tetraquarks. They too conclude that those made from bb pairs should be stable, while others containing charm quarks should break down into pairs of mesons.

Reassuring conclusion

Karliner finds it “very reassuring” that the two studies reach essentially the same conclusion, even if, as he points out, “there is some difference in the specific numbers”. He is also optimistic that the bbu d particle can be discovered experimentally, estimating that this should occur about two to three years after LHCb has had its effective luminosity boosted by a factor of five – an upgrade expected to take place in 2021.

Tim Gershon of the University of Warwick, who is UK spokesperson for LHCb, is a little more cautious, arguing that “it will take some time” to understand the sensitivity of current experiments to bbu d. He says that the tetraquark’s weak decay will generate “a striking experimental signature” but that the signature will only emerge after vast numbers of collisions have been analysed. Nevertheless, he adds, “we can overcome very small probabilities with very large data samples”, noting that LHCb may get a second upgrade in the 2030s to make best use of the high-luminosity LHC. “I tend to think that the prospects are reasonably good in the long term,” he says.

The research is described in two papers in *Physical Review Letters*.

Quarks take wrong turns

"That's very disturbing," comments theoretical physicist Xiangdong Ji of the University of Maryland at College Park.

The finding suggests that scientists may have erred in calculations using fundamental theory to predict quark behavior within neutrons, he says. It might also indicate that orbital motions of particles within neutrons, in addition to those particles' spins, are more important than previously recognized. Those motions might be akin to the moon's rotation around Earth as the satellite also spins about its own axis.

Given that neutrons and protons are sister particles, called nucleons, the new findings apply to both, says Xiaochao Zheng, a member of the experimental team who's now at Argonne (Ill.) National Laboratory.

Nucleons are the building blocks of atomic nuclei. A typical nucleon includes three quarks: two down quarks and one up quark for a neutron; two up quarks and one down quark for a proton. In addition to those so-called valence quarks, each nucleon contains multitudes of gluons—particles that bind quarks—and of short-lived quark-antiquark pairs, known collectively as the quark sea.

Each of these constituents of a nucleon carries some share of the nucleon's energy, although the distribution of that energy among the constituents constantly shifts, Ji explains.

From previous experiments, scientists knew that only valence quarks can grab major portions of a nucleon's total energy content, says Jian-Ping Chen of the Jefferson lab, a coleader of the experiment. The new spin-detecting experiment is the first to measure the state of the neutron when most of its energy momentarily resides in a single quark.

Calculations based on the prevailing theory of quark behavior predict that any quark holding more than about half the energy of a nucleon should spin in the same direction as the nucleon. However, when the new experiment probed valence quarks temporarily laden with up to 60 percent of a neutron's energy, it revealed that only the up quarks behaved as expected. The down quarks somehow carried most of the energy yet rotated in a direction opposite to that of the neutron as a whole.

Electrons and entire atoms also have spins. To arrive at the new findings, the experimenters made a target of helium gas in which nearly all atoms were forced to spin in the same direction and bombarded it with a beam of high-energy electrons, whose spins were also forced to have uniform orientations.

The researchers determined the spin orientations of the quarks in the helium atoms by placing detectors in specific positions where they are more likely to make detections when the orientations of the electron's spin and the quark's spin are opposite, Zheng says. She and her colleagues present their results in the Jan. 9 Physical Review Letters. [10]

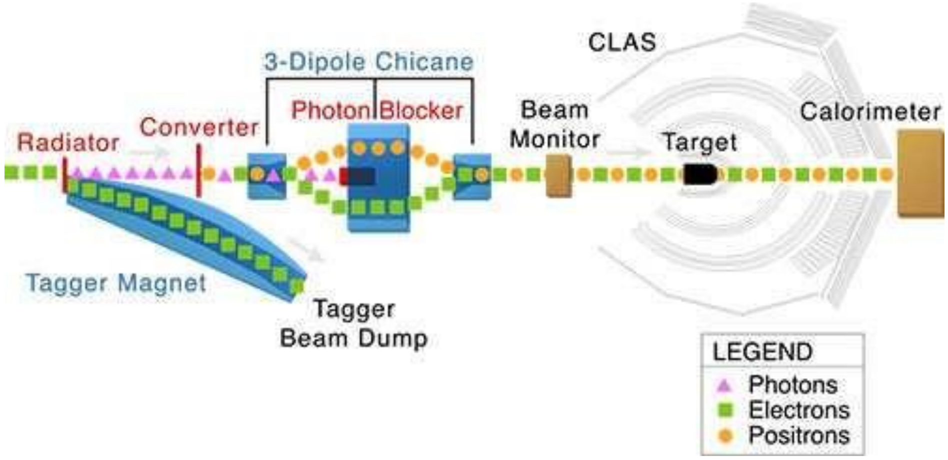
Scientists Mix Matter and Anti-Matter to Resolve Decade-Old Proton Puzzle

Nuclear physicists have used two different methods to measure the proton’s electric form factor. But the deeper that they probe inside the proton, the more the results from these two different methods disagree. Eventually, the measurements provided by one method amount to about five times the quantity yielded by the other. This huge discrepancy is much larger than the experimental uncertainty in the measurements.

“The proposed solution for the discrepancy is that the analysis of one set of measurements was too simplistic,” says Larry Weinstein, a professor of physics at Old Dominion University. “And that if we include something that is known as the two-photon effect, they both should agree.”

The effect is a result of the manner in which nuclear scientists conduct their probes of the proton. The proton is probed by bombarding it with energetic electrons and observing how the two particles interact. Most of the time, this interaction consists of the electron exchanging a single virtual photon with the proton. A virtual photon is just a packet of energy that an electron gives up to the proton as it collides with the particle. But sometimes, the electron interacts with the proton differently; it may conjure up two virtual photons that it passes on to the proton.

“Normally, when an electron scatters off of a proton or off of a nucleus, it does it by exchanging a single virtual photon. Like two skaters passing by each other, and one throws a medicine ball to the other; it helps push them apart,” Weinstein explains. “Because the electromagnetic interaction is very weak, we expect that the second photon, second medicine ball, is only exchanged a few percent of the time. But that few percent effect could be big enough to explain this huge difference between the measurements of the proton’s electric form factor.”



This diagram shows the basic layout of the beam (electrons and positrons) and the magnets, target and detectors for Experiment E04-116 conducted using the CEBAF Large Acceptance Spectrometer in Experimental Hall B.

So, nuclear scientists needed a good measurement of how often an electron is likely to generate two photons via this two-photon effect. But there was a big problem: no one had ever measured this effect, and calculating it to any level of accuracy was too difficult due to the complexity of the proton.

To get that quantity, Weinstein and his colleagues turned to mixing matter with anti-matter.

It turns out that, while measuring the two-photon effect directly may be too difficult to do now, the scientists could instead measure a different quantity that relates to the effect. The two-photon effect can be measured indirectly by noting how often the electron interacts with the proton and comparing that to how often the electron’s anti-matter twin, the positron, interacts with the proton. The difference between electron and positron interactions calibrates the strength of the two photon effect and its effect on the form factor measurements.

Using the Continuous Electron Beam Accelerator Facility, or CEBAF, at Jefferson Lab, Weinstein and his colleagues set out to make the measurement in the winter of 2010. They started with a beam of electrons, which they then passed through two gold foils and a few magnets to produce a beam composed of electrons and positrons. This beam was then directed onto the protons of a hydrogen target.

They then collected data on the electron-proton and positron-proton collisions with the CLAS spectrometer. Since an experiment like this had never been done before, it took them four years to analyze the data and extract precise results.

“There actually was a few percent difference. We got a few percent more positron-proton scattering events than electron-proton scattering events,” Weinstein says.
“So, our measurement agrees with the calculation, and the calculation accounts for most of the discrepancy between the two measurements of the proton’s electric form factor.”

According to the researchers, this means that the differences in the measurements of the proton’s electric form factor, which provides information on how quarks are distributed inside the proton, can be accounted for by the two-photon effect.

Two other research groups, the VEPP-3 collaboration at Novosibirsk and the OLYMPUS collaboration at DESY, have also been measuring this effect, although with single beams of electrons that they compare to single beams of positrons. VEPP-3 measured similar results and OLYMPUS collaborators are still analyzing their data. [9]

Asymmetry in the interference occurrences of oscillators

The asymmetrical configurations are stable objects of the real physical world, because they cannot annihilate. One of the most obvious asymmetry is the proton – electron mass rate $M_p = 1840\ M_e$ while they have equal charge. We explain this fact by the strong interaction of the proton, but how remember it his strong interaction ability for example in the H – atom where are only electromagnetic interactions among proton and electron.

This gives us the idea to origin the mass of proton from the electromagnetic interactions by the way interference occurrences of oscillators. The uncertainty relation of Heisenberg makes sure that the particles are oscillating.

The resultant intensity due to n equally spaced oscillators, all of equal amplitude but different from one another in phase, either because they are driven differently in phase or because we are looking at them an angle such that there is a difference in time delay:

$$(1) \qquad I = I_0 \sin^2 n\,\varphi/2 \,/\, \sin^2 \varphi/2$$

If φ is infinitesimal so that $\sin\varphi = \varphi$ than

$$(2) \qquad \iota = n^2 \iota_0$$

This gives us the idea of

$$(3) \qquad M_p = n^2 M_e$$

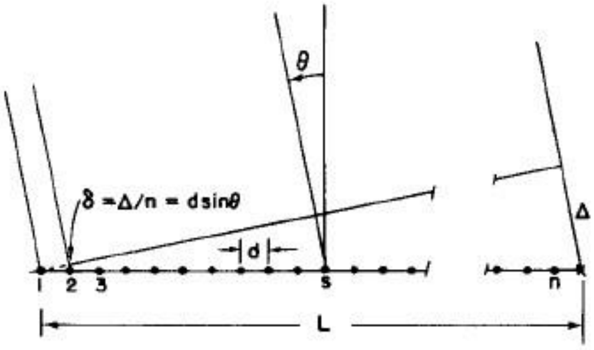


Fig. 30–3. A linear array of n equal oscillators, driven with phases $\alpha_s = s\alpha$.

Figure 1.) A linear array of n equal oscillators

There is an important feature about formula (1) which is that if the angle φ is increased by the multiple of 2π it makes no difference to the formula.

So

(4) $d \sin \theta = m \lambda$ and we get m-order beam if λ less than d. [6]

If d less than λ we get only zero-order one centered at $\theta = 0$. Of course, there is also a beam in the opposite direction. The right chooses of d and λ we can ensure the conservation of charge.

For example

(5) $2(m+1) = n$

Where $2(m+1) = N_p$ number of protons and $n = N_e$ number of electrons.

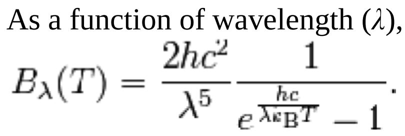
In this way we can see the H_2 molecules so that 2n electrons of n radiate to 4(m+1) protons, because $d_e > \lambda_e$ for electrons, while the two protons of one H_2 molecule radiate to two electrons of them, because of $d_e < \lambda_e$ for this two protons.

To support this idea we can turn to the Planck distribution law, that is equal with the Bose – Einstein statistics.

Spontaneously broken symmetry in the Planck distribution law

The Planck distribution law is temperature dependent and it should be true locally and globally. I think that Einstein's energy-matter equivalence means some kind of existence of electromagnetic oscillations enabled by the temperature, creating the different matter formulas, atoms molecules, crystals, dark matter and energy.

Max Planck found for the black body radiation



As a function of wavelength (λ), Planck's law is written as:

$$B_\lambda(T) = \frac{2hc^2}{\lambda^5}\frac{1}{e^{\frac{hc}{\lambda k_B T}} - 1}.$$

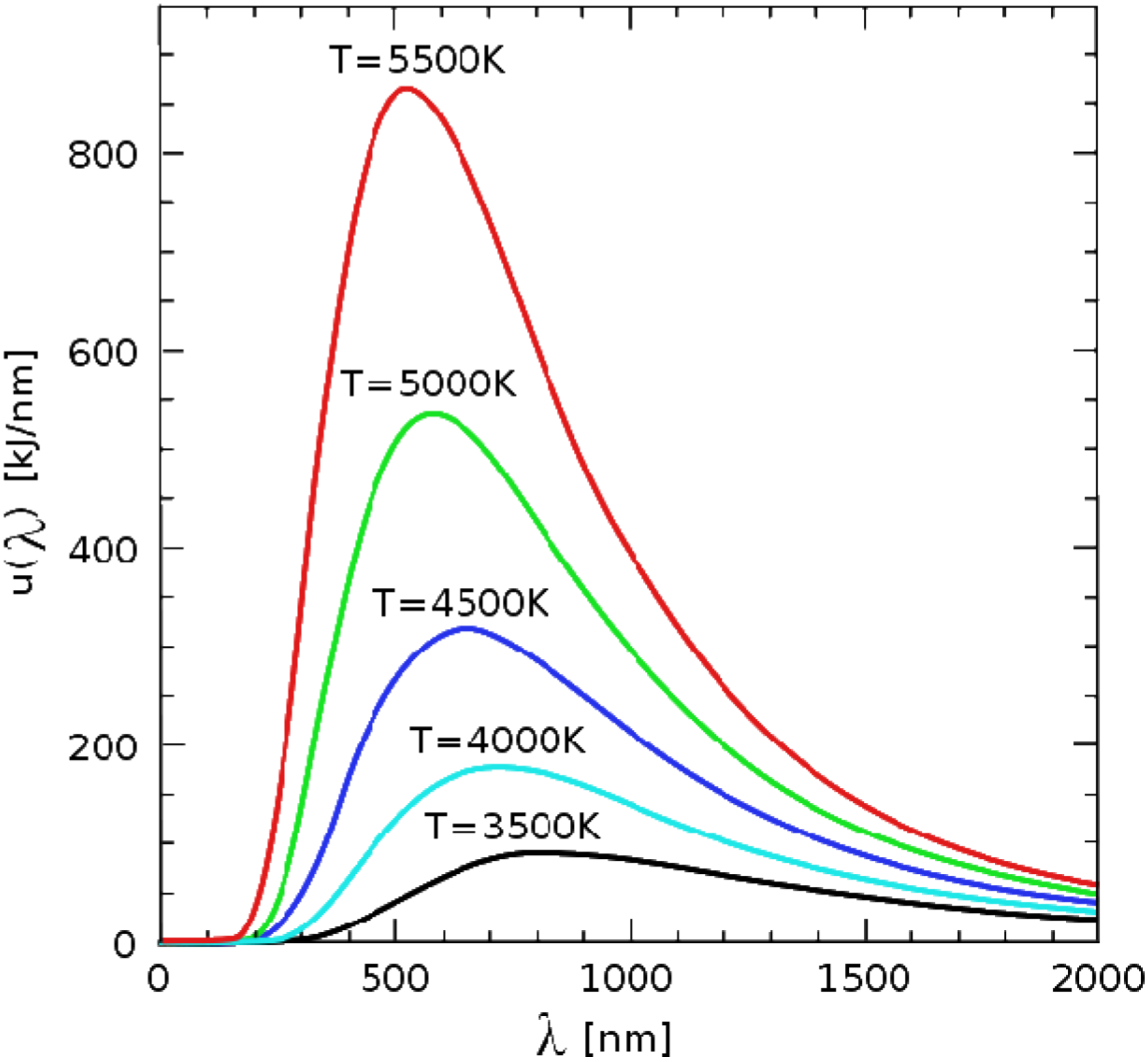


Figure 2. The distribution law for different T temperatures

We see there are two different λ_1 and λ_2 for each T and intensity, so we can find between them a d so that $\lambda_1 < d < \lambda_2$.

We have many possibilities for such asymmetrical reflections, so we have many stable oscillator configurations for any T temperature with equal exchange of intensity by radiation. All of these configurations can exist together. At the λ_{max} is the annihilation point where the configurations are symmetrical. The λ_{max} is changing by the Wien's displacement law in many textbooks.

(7) $$\lambda_{\max} = \frac{b}{T}$$

> where $\lambda_{\max}$ is the peak wavelength, T is the absolute temperature of the black body, and b is a constant of proportionality called *Wien's displacement constant*, equal to $2.8977685(51)\times10^{-3}$ m·K (2002 CODATA recommended value).

By the changing of T the asymmetrical configurations are changing too.

The structure of the proton

We must move to the higher T temperature if we want look into the nucleus or nucleon arrive to $d<10^{-13}$ cm. [2] If an electron with $\lambda_e < d$ move across the proton then by (5) $2(m+1) = n$ with $m = 0$ we get $n = 2$ so we need two particles with negative and two particles with positive charges. If the proton can fraction to three parts, two with positive and one with negative charges, then the reflection of oscillators are right. Because this very strange reflection where one part of the proton with the electron together on the same side of the reflection, the all parts of the proton must be quasi lepton so $d > \lambda_q$. One way dividing the proton to three parts is, dividing his oscillation by the three direction of the space. We can order 1/3 e charge to each coordinates and 2/3 e charge to one plane oscillation, because the charge is scalar. In this way the proton has two +2/3 e plane oscillation and one linear oscillation with -1/3 e charge. The colors of quarks are coming from the three directions of coordinates and the proton is colorless. The flavors of quarks are the possible oscillations differently by energy and if they are plane or linear oscillations. We know there is no possible reflecting two oscillations to each other which are completely orthogonal, so the quarks never can be free, however there is asymptotic freedom while their energy are increasing to turn them to orthogonal. If they will be completely orthogonal then they lose this reflection and take new partners from the vacuum. Keeping the symmetry of the vacuum the new oscillations are keeping all the conservation laws, like charge, number of baryons and leptons. The all features of gluons are coming from this model. The mathematics of reflecting oscillators show Fermi statistics.

Important to mention that in the Deuteron there are 3 quarks of +2/3 and -1/3 charge, that is three u and d quarks making the complete symmetry and because this its high stability.

The weak interaction

The weak interaction transforms an electric charge in the diffraction pattern from one side to the other side, causing an electric dipole momentum change, which violates the CP and time reversal symmetry.

Another important issue of the quark model is when one quark changes its flavor such that a linear oscillation transforms into plane oscillation or vice versa, changing the charge value with 1 or -1. This kind of change in the oscillation mode requires not only parity change, but also charge and time changes (CPT symmetry) resulting a right handed anti-neutrino or a left handed neutrino.

The right handed anti-neutrino and the left handed neutrino exist only because changing back the quark flavor could happen only in reverse, because they are different geometrical constructions, the u is 2 dimensional and positively charged and the d is 1 dimensional and negatively charged. It needs also a time reversal, because anti particle (anti neutrino) is involved.

The neutrino is a 1/2spin creator particle to make equal the spins of the weak interaction, for example neutron decay to 2 fermions, every particle is fermions with ½ spin. The weak interaction changes the entropy since more or less particles will give more or less freedom of movement. The entropy change is a result of temperature change and breaks the equality of oscillator diffraction intensity of the Maxwell–Boltzmann statistics. This way it changes the time coordinate measure and makes possible a different time dilation as of the special relativity.

The limit of the velocity of particles as the speed of light appropriate only for electrical charged particles, since the accelerated charges are self maintaining locally the accelerating electric force. The neutrinos are CP symmetry breaking particles compensated by time in the CPT symmetry, that is the time coordinate not works as in the electromagnetic interactions, consequently the speed of neutrinos is not limited by the speed of light.

The weak interaction T-asymmetry is in conjunction with the T-asymmetry of the second law of thermodynamics, meaning that locally lowering entropy (on extremely high temperature) causes the weak interaction, for example the Hydrogen fusion.

Probably because it is a spin creating movement changing linear oscillation to 2 dimensional oscillation by changing d to u quark and creating anti neutrino going back in time relative to the proton and electron created from the neutron, it seems that the anti neutrino fastest then the velocity of the photons created also in this weak interaction?

A quark flavor changing shows that it is a reflection changes movement and the CP- and T-symmetry breaking. This flavor changing oscillation could prove that it could be also on higher level such as atoms, molecules, probably big biological significant molecules and responsible on the aging of the life.
Important to mention that the weak interaction is always contains particles and antiparticles, where the neutrinos (antineutrinos) present the opposite side. It means by Feynman's interpretation that these particles present the backward time and probably because this they seem to move faster than the speed of light in the reference frame of the other side.

Finally since the weak interaction is an electric dipole change with ½ spin creating; it is limited by the velocity of the electromagnetic wave, so the neutrino's velocity cannot exceed the velocity of light.

The Strong Interaction - QCD

Confinement and Asymptotic Freedom

For any theory to provide a successful description of strong interactions it should simultaneously exhibit the phenomena of confinement at large distances and asymptotic freedom at short distances. Lattice calculations support the hypothesis that for non-abelian gauge theories the two domains are analytically connected, and confinement and asymptotic freedom coexist.
Similarly, one way to show that QCD is the correct theory of strong interactions is that the coupling extracted at various scales (using experimental data or lattice simulations) is unique in the sense that its variation with scale is given by the renormalization group. The data for αs is reviewed in Section
19. In this section I will discuss what these statements mean and imply. [4]

Lattice QCD

Lattice QCD is a well-established non-perturbative approach to solving the quantum chromodynamics (QCD) theory of quarks and gluons. It is a lattice gauge theory formulated on a grid or lattice of points in space and time. When the size of the lattice is taken infinitely large and its sites infinitesimally close to each other, the continuum QCD is recovered. [6]

Analytic or perturbative solutions in low-energy QCD are hard or impossible due to the highly nonlinear nature of the strong force. This formulation of QCD in discrete rather than continuous space-time naturally introduces a momentum cut-off at the order $1/a$, where a is the lattice spacing, which regularizes the theory. As a result, lattice QCD is mathematically well-defined. Most importantly, lattice QCD provides a framework for investigation of nonperturbative phenomena such as confinement and quark-gluon plasma formation, which are intractable by means of analytic field theories.

In lattice QCD, fields representing quarks are defined at lattice sites (which leads to fermion doubling), while the gluon fields are defined on the links connecting neighboring sites.

QCD

QCD enjoys two peculiar properties:

- **Confinement**, which means that the force between quarks does not diminish as they are separated. Because of this, it would take an infinite amount of energy to separate two quarks; they are forever bound into hadrons such as the proton and the neutron. Although analytically unproven, confinement is widely believed to be true because it explains the consistent failure of free quark searches, and it is easy to demonstrate in lattice QCD.
- **Asymptotic freedom**, which means that in very high-energy reactions, quarks and gluons interact very weakly. This prediction of QCD was first discovered in the early 1970s by

> David Politzer and by Frank Wilczek and David Gross. For this work they were awarded the 2004 Nobel Prize in Physics.

There is no known phase-transition line separating these two properties; confinement is dominant in low-energy scales but, as energy increases, asymptotic freedom becomes dominant. [5]

Color Confinement

When two quarks become separated, as happens in particle accelerator collisions, at some point it is more energetically favorable for a new quark-antiquark pair to spontaneously appear, than to allow the tube to extend further. As a result of this, when quarks are produced in particle accelerators, instead of seeing the individual quarks in detectors, scientists see "jets" of many color-neutral particles (mesons and baryons), clustered together. This process is called hadronization, fragmentation, or string breaking, and is one of the least understood processes in particle physics.

[3]

Electromagnetic inertia and mass

Electromagnetic Induction

Since the magnetic induction creates a negative electric field as a result of the changing acceleration, it works as an electromagnetic inertia, causing an electromagnetic mass. [1]

The frequency dependence of mass

Since $E = h\nu$ and $E = mc^2$, $m = h\nu / c^2$ that is the m depends only on the ν frequency. It means that the mass of the proton and electron are electromagnetic and the result of the electromagnetic induction, caused by the changing acceleration of the spinning and moving charge! It could be that the m_o inertial mass is the result of the spin, since this is the only accelerating motion of the electric charge. Since the accelerating motion has different frequency for the electron in the atom and the proton, they masses are different, also as the wavelengths on both sides of the diffraction pattern, giving equal intensity of radiation.

Electron – Proton mass rate

The Planck distribution law explains the different frequencies of the proton and electron, giving equal intensity to different lambda wavelengths! Also since the particles are diffraction patterns they have some closeness to each other. [2]

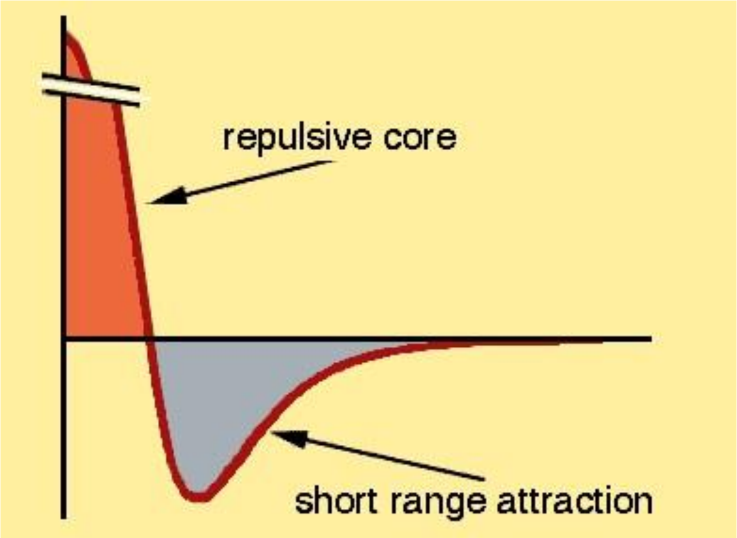
There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a high probability event. The asymmetric sides are creating different frequencies of electromagnetic radiations being in the same intensity level and compensating each other. One of these compensating ratios is the electron – proton mass ratio. The lower energy side has no compensating intensity level, it is the dark energy and the corresponding matter is the dark matter.

The potential of the diffraction pattern

The force that holds protons and neutrons together is extremely strong. It has to be strong to overcome the electric repulsion between the positively charged protons. It is also of very short range, acting only when two particles are within 1 or 2 fm of each other.

1 fm (femto meter) = 10^{-15} m = 10^{-15} m = 0.000000000000001 meters.

The qualitative features of the nucleon-nucleon force are shown below.



There is an extremely **strong short-range repulsion** that pushes protons and neutrons apart before they can get close enough to touch. (This is shown in orange.) This repulsion can be understood to arise because the quarks in individual nucleons are forbidden to be in the same area by the Pauli Exclusion Principle.

There is a **medium-range attraction** (pulling the neutrons and protons together) that is strongest for separations of about 1 fm. (This is shown in gray.) This attraction can be understood to arise from the exchange of quarks between the nucleons, something that looks a lot like the exchange of a pion when the separation is large.

The density of nuclei is limited by the short range repulsion. The maximum size of nuclei is limited by the fact that the attractive force dies away extremely quickly (exponentially) when nucleons are more than a few fm apart.

Elements beyond uranium (which has 92 protons), particularly the trans-fermium elements (with more than 100 protons), tend to be unstable to fission or alpha decay because the Coulomb repulsion between protons falls off much more slowly than the nuclear attraction. This means that each proton sees repulsion from every other proton but only feels an attractive force from the few neutrons and protons that are nearby -- even if there is a large excess of neutrons.

Some "super heavy nuclei" (new elements with about 114 protons) might turn out to be stable as a result of the same kind of quantum mechanical shell-closure that makes noble gases very stable chemically. [7]

Conclusions

Now that the proton-puzzle is apparently resolved, nuclear scientists will further explore the proton's electric form factor, revealing where quarks are in the proton, and the proton's magnetic form factor, revealing how quarks are moving inside the proton, to gain better insight into how quarks build protons. [9]

Lattice QCD gives the same results as the diffraction theory of the electromagnetic oscillators, which is the explanation of the strong force and the quark confinement. [8]

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