Hypothetical New Particle

The physicists describe the hypothetical new particle as an "electrophobic scalar boson." Currently there are five bosons in the standard model, only one of which is a scalar (the Higgs), meaning it has zero spin. All five bosons have been experimentally confirmed, and all are force carriers that play a role in holding matter together. [14]

It may only take scientists a few more years to solve one of the biggest puzzles in modern elementary particle physics, the so-called "muon mystery." Russian scientists from the National Research Nuclear University (MEPhI) will make a significant contribution to this research. [13]

A large team made up of researchers from across the globe has repeated experiments conducted several years ago that showed a different radius for a proton when it was orbited by a muon as opposed to an electron—a finding dubbed the proton radius puzzle—using a deuterium nucleus this time and has found the same puzzle. In their paper published in the journal Science, the team describes the experiments they conducted, what they found and offer a few possible ideas to help dispel the notion that the puzzle indicates that there may be some problems with the Standard Model. [12]

The resolution of the Proton Radius Puzzle is the diffraction pattern, giving another wavelength in case of muonic hydrogen oscillation for the proton than it is in case of normal hydrogen because of the different mass rate.

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!

Hypothetical new particle could solve two major problems in particle physics

Although the Large Hadron Collider's enormous 13 TeV energy is more than sufficient to detect many particles that theorists have predicted to exist, no new particles have been discovered since the Higgs boson in 2012. While the absence of new particles is informative in itself, many physicists are still yearning for some hint of "new physics," or physics beyond the standard model.

In a new paper published in Physical Review Letters, physicists Yu-Sheng Liu, David McKeen, and Gerald A. Miller at the University of Washington in Seattle have hypothesized the existence of a new particle that looks very enticing because it could simultaneously solve two important problems: the proton radius puzzle and a discrepancy in muon anomalous magnetic moment measurements that differ significantly from standard model predictions.

"The new particle can account for two seemingly unrelated problems," Miller told Phys.org. "We also point out several experiments that can further test our hypothesis."

The physicists describe the hypothetical new particle as an "electrophobic scalar boson." Currently there are five bosons in the standard model, only one of which is a scalar (the Higgs), meaning it has zero spin. All five bosons have been experimentally confirmed, and all are force carriers that play a role in holding matter together.

One of the distinct features of the new hypothetical particle is that, although it is predicted to bind to protons and neutrons, it would bind very weakly or not at all to electrons, making it "electrophobic." The scientists showed that this electrophobic property would allow the particle to solve both the proton and muon problems.

In the proton radius puzzle, the problem is that the proton radius seems to have a different size depending on what type of particle is orbiting it. Experiments have found that the proton radius is slightly larger when it is orbited by an electron than when it is orbited by a muon, which is identical to the electron except for being 200 times heavier. Assuming that the discrepancy is not due to measurement error (which it very well may be, considering how difficult it is to measure a particle that is less than a femtometer [10-15 meters] across), the results may point to the existence of a previously unknown fundamental force that pulls protons and muons closer together, but does not act between protons and electrons.

"The principle of lepton universality is a pillar of the standard model," Miller said, referring to the idea that all leptons, including electrons and muons, should behave in the same way. "Our particle violates this principle, because interactions with muons and electrons are different."

The second problem involves the muon's anomalous magnetic moment, which is a measure of how quantum effects contribute to the magnetic moment of a particle.

So far, the most precise measurement disagrees with the standard model by more than three standard deviations. Once again, physicists think that the discrepancy may indicate physics beyond the standard model, or else more accurate measurements are needed. If the answer is new physics, then the new particle suggests that the proton and muon problems may be related.

"The proton radius puzzle can be explained if there is a new additional attractive interaction between the muon and proton," Miller said. "Such an interaction must also contribute to the muon anomalous magnetic moment. The proton radius puzzle (contribution to the Lamb shift) determines the strength of the interaction that contributes to the muon anomalous magnetic moment. The new contribution is just large enough to account for the current disagreement between theory and experiment. The equations in our paper allow us to obtain definite numbers, and these numbers can work out to be just right to account for both puzzles. New experiments will determine whether this is true physics or just a coincidence."

The physicists emphasize that they make no assumptions about the hypothetical particle other than that it could explain both of these puzzles. By constraining the mass of the hypothetical particle using data from previous experiments, the physicists predict that its mass would lie somewhere between 100 keV and 100 MeV.

Although previous experiments have already explored part of this predicted range, the physicists have identified two unexplored regions that may be ideal places to look. They expect that future high-precision experiments involving protons and muons may be able to search for the particle in these regions.

"We constrain the parameter space (mass and couplings) of this new particle in a finite range (except for the coupling of electrons)," Liu said. "So experimentalists can discover or exclude it by looking at a specific place, instead of measuring zero more and more accurately, like in the electron experiments."

In the meantime, the physicists are also looking forward to improved measurements of the muon anomalous magnetic moment—if the discrepancy remains, the results will offer further support for the existence of the new particle. The scientists also plan to apply some of the methods they developed here to look for other new particles.

"Our work on this has allowed us to develop new theoretical tools to aid in the search for other kinds of bosons with different quantum numbers," Miller said. "We will be applying those tools. Another direction is to develop a deeper theory that accommodates our new boson." [14]

Russian scientists on the verge of solving the 'muon mystery'

It may only take scientists a few more years to solve one of the biggest puzzles in modern elementary particle physics, the so-called "muon mystery." Russian scientists from the National Research Nuclear University (MEPhI) will make a significant contribution to this research.

Cosmic ray particles in the Earth's atmosphere undergo a series of transformations and, as a result, produce elementary particles or muons. Muons reach the Earth's surface and can therefore be registered by ground-based detectors. Several years ago, scientists noticed that the number of registered muons is by tens of percentage points higher than it should be, according to existing theories. This phenomenon was called the muon mystery.

The first clue to the muon mystery was found in 2002-2007 during a long series of experiments on the DECOR facility in MEPhI. Later, the excess of muons was confirmed by experiments at the Pierre Auger Observatory in Argentina.

NEVOD Scientific and Educational Center, which is a subdivision of the Institute of Nuclear Physics and Engineering of MEPhI, is studying muons with the world's only multi-purpose neutrino water detector, which is used to research all cosmic ray components near the Earth's surface. MEPhI researchers spoke about the latest results of the cosmic ray experiments with NEVOD at the National Cosmic Ray Conference in Dubna, Moscow Region.

"In the past several years, we have increased the amount of experimental data three- or four-fold and, as a result, improved the precision of measurements. One of the tasks in the muon mystery experimental research is to count not only the number of muons but to measure their energy characteristics. We started the experiment of measuring the energies of muons back in 2012, and it is still in progress. First, we used the coordinate-tracking detector DECOR to register a group of muons. Then we measured what energy they deposited in the NEVOD Cherenkov water detector," said Rostislav Kokoulin, NEVOD Senior Research Associate.

The scientists intend to find out whether the mean energy of muons has changed, in addition to their excess number.

"When the experiment proves the excess of energy exists, it will become clear what changes in the theoretical model are required. Now MEPhI is building new facilities that will operate alongside DECOR and NEVOD. This will allow the scientists to expand the set of characteristics under observation and make the measurements more precise."

Kokoulin added that the solution to the "muon mystery" is a question of three to five years.

"Once the muon mystery is solved, we will have a more accurate idea of the nuclear cascade process initiated by interactions of ultra-high energy particles. This understanding is required for studying characteristics of the universe and the processes within it," the scientist stressed. [13]

New measurement with deuterium nucleus confirms proton radius puzzle is real

A large team made up of researchers from across the globe has repeated experiments conducted several years ago that showed a different radius for a proton when it was orbited by a muon as opposed to an electron—a finding dubbed the proton radius puzzle—using a deuterium nucleus this time and has found the same puzzle. In their paper published in the journal Science, the team describes the experiments they conducted, what they found and offer a few possible ideas to help dispel the notion that the puzzle indicates that there may be some problems with the Standard Model.

Scientists have been able to calculate the radius of a proton (0.88 ± 0.01 femtometers) for some time using the charge of the proton that orbits around it and doing so has helped confirm theories regarding the Standard Model. But, in trying to improve the accuracy of the measurement by using a muon, (which orbits closer to the proton) researchers at the Max Planck Institute back in 2010 found a different radius—one that was 7 deviations from what was considered the official value.

This proton radius puzzle has had physicists scratching their heads ever since because it suggests there is an error in the Standard Model somewhere. Over the past six years various researchers have offered theories to solve the puzzle, most of which have involved ways to preserve the Standard Model, but to date, the puzzle still remains.

In this latest effort the researchers sought to gain more insight into the problem by adding another piece to the puzzle, a neutron, i.e. by using a deuterium nucleus.

Their thinking was that the presence of the neutron would change the way that electrons and muons perceived the proton charge. They report that they found that the measurement they made of the radius of the proton was still different from that found with just an electron and proton, by approximately 7.5 sigma.

The results by the team offer no new explanations for the measurement discrepancies—it remains a puzzle, but they do offer some possible avenues for further investigation, e.g. ways to improve measurements and forcing muons to interact with the protons to see if there might be any evidence of an unknown force at work. [12]

The Proton Radius Puzzle

Officially, the radius of a proton is 0.88 ± 0.01 femtometers (fm, or 10^{-15} m). Researchers attained that value using two methods: first, by measuring the proton's energy levels using hydrogen spectroscopy, and second, by using electron scattering experiments, where an electron beam is shot at a proton and the way the electrons scatter is used to calculate the proton's size.

But when trying to further improve the precision of the proton radius value in 2010 with a third experimental technique, physicists got a value of 0.842 ± 0.001 fm—a difference of 7 deviations from the official value. These experiments used muonic hydrogen, in which a negatively charged muon orbits around the proton, instead of atomic hydrogen, in which an electron orbits around the proton. Because a muon is 200 times heavier than an electron, a muon orbits closer to a proton than an electron does, and can determine the proton size more precisely.

This inconsistency between proton radius values, called the "proton radius puzzle," has gained a lot of attention lately and has led to several proposed explanations. Some of these explanations include new degrees of freedom beyond the Standard Model, as well as extra dimensions. [9]

Taking into account the Electro-Strong Interaction we have a simple explanation of this puzzle.

In the muonic hydrogen the muon/proton mass rate different from the electron/proton mass rate of the normal hydrogen, giving exactly the measured difference for the proton's radius, using the diffraction pattern of the Electro-Strong Interaction.

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) $I = I_0 \sin^2 n\, \phi/2 \,/\, \sin^2 \phi/2$

If ϕ is infinitesimal so that $\sin\phi = \phi$, than

(2) $I = n^2 I_0$

This gives us the idea of

(3) $M_p = n^2 M_e$

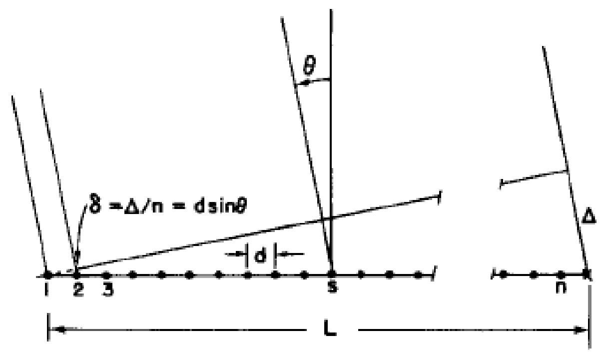


Fig. 30–3. A linear array of n equal oscillators, driven with phases $\alpha_s = s\alpha$.

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:

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

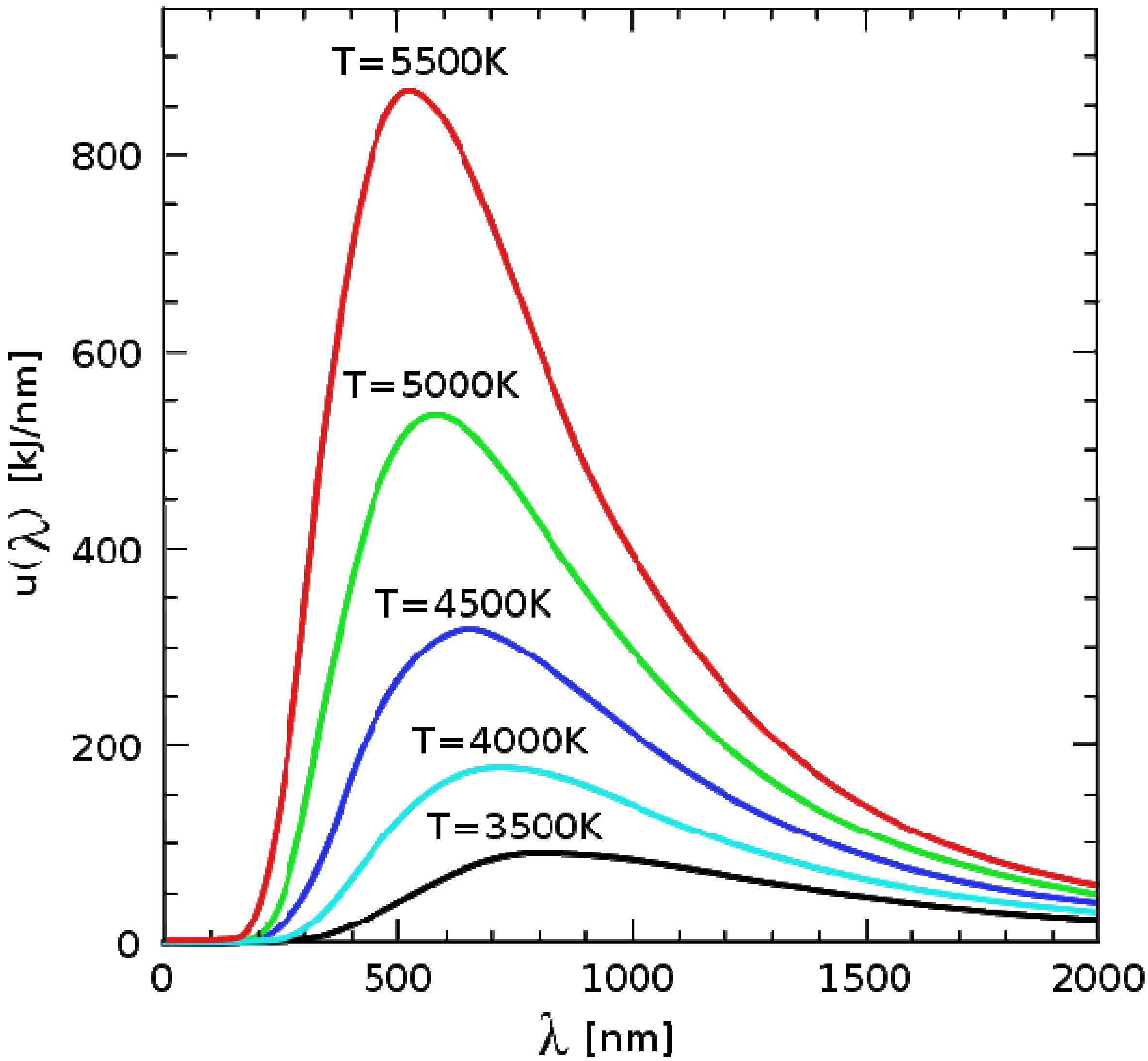


Figure 2. The distribution law for different T temperatures

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 an asymptotic freedom while their energy are increasing to turn them to the orthogonally. 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 non-perturbative 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]

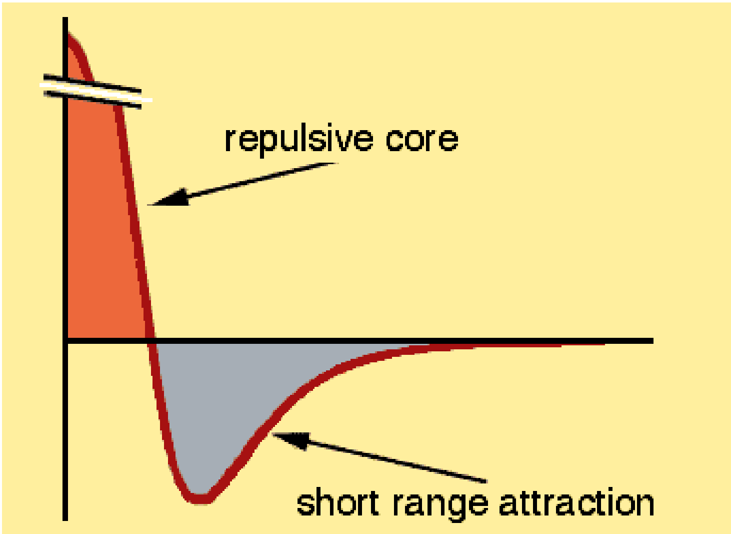
There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a 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]

Experiments with explanation

We present the results of experimental and theoretical study of the scattering of low energy pμ atoms in solid hydrogen cooled to 3 K. The resulting emission of low energy pμ atoms from the hydrogen layer into the adjacent vacuum was much higher than that predicted by calculations which ignored the solid nature of the hydrogen. [11]

Conclusions

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]

The resolution of the Proton Radius Puzzle is the diffraction pattern of the electromagnetic oscillations, giving different proton radius for muon-proton diffraction.

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