Weakly-Interacting Supersymmetric Particles

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If researchers at Florida Institute of Technology, employing pioneering new methods, are able to determine the top quark's mass at a level of precision as yet unachieved, they will move science closer to understanding whether the universe is stable, as we have long believed to be the case, or unstable. [16]

Last February, scientists made the groundbreaking discovery of gravitational waves produced by two colliding black holes. Now researchers are expecting to detect similar gravitational wave signals in the near future from collisions involving neutron stars—for example, the merging of two neutron stars to form a black hole, or the merging of a neutron star and a black hole. [15]

In a new study published in EPJ A, Susanna Liebig from Forschungszentrum Jülich, Germany, and colleagues propose a new approach to nuclear structure calculations. The results are freely available to the nuclear physicists' community so that other groups can perform their own nuclear structure calculations, even if they have only limited computational resources. [14]

The PHENIX detector at the Relativistic Heavy Ion Collider (RHIC), a particle accelerator at Brookhaven National Laboratory uniquely capable of measuring how a proton's internal building blocks — quarks and gluons — contribute to its overall intrinsic angular momentum, or "spin." [13]

More realistic versions of lattice QCD may lead to a better understanding of how quarks formed hadrons in the early Universe.

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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Author: George Rajna

Preface

More realistic versions of lattice QCD may lead to a better understanding of how quarks formed hadrons in the early Universe.

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!

ATLAS releases new results in search for weakly-interacting supersymmetric particles

Supersymmetry is an extension to the Standard Model that may explain the origin of dark matter and pave the way to a grand unified theory of nature. For each particle of the Standard Model, supersymmetry introduces an exotic new "super-partner," which may be produced in proton-proton collisions. Searching for these particles is currently one of the top priorities of the LHC physics program. A discovery would transform our understanding of the building blocks of matter and the fundamental forces, leading to a paradigm shift in physics similar to when Einstein's relativity superseded classical Newtonian physics in the early 20th century.

Supersymmetric particles (or "sparticles") are grouped into two categories with different properties that depend on the strength of their interactions with protons. Strongly-interactingsparticles may be produced with large rates and lead to striking, energetic events in the detector. Weakly-interacting sparticles are produced at lower rates and lead to less striking signatures, making them more difficult to distinguish from Standard Model background processes.

Since the LHC collision energy was increased from 8 to 13 trillion electron volts (TeV) in Run 2 to enhance the discovery reach, a wide variety of searches for strongly-interacting sparticles have been performed. Null results in these searches indicate that if they exist, strongly-interacting sparticles must be very heavy – at least several hundred times heavier than the proton. Due to the smaller production rates, larger data samples are required to probe weakly-interacting sparticles, and more optimized selection criteria are required to tease apart the small signal from the background.

ATLAS physicists presented one of the first Run 2 searches for weakly-interacting sparticles at the LHCP 2017 conference. The search targets the production of sparticles called charginos, heavy neutralinos, and sleptons. If produced at the LHC, these particles would decay to leptons (electrons or their heavier cousins, the muons) and stable dark matter particles called light neutralinos. These dark matter neutralinos would carry away unseen energy since they do not interact with the detector, leading to unbalanced collision events that appear to violate momentum conservation. This "missing transverse momentum" is the key signature exploited by the ATLAS detector to infer the production of dark matter particles.

The analysis selected collision events containing two or three electrons and muons and large missing transverse momentum. The figure shows the measured distribution (data points) of missing transverse momentum in events with three leptons, compared to that expected from the Standard

Model (coloured histogram). No significant deviation from the expectation was observed. The results were used to set stringent limits on weakly-interacting sparticles with masses as large as 1150 billion electron volts (GeV), the heaviest such particles yet probed at ATLAS.

Weakly-interacting sparticles may have eluded detection in this search if they are produced with very small rates or do not produce much energy in the detector. Both of these features are expected in models with light higgsinos, the super-partners of the Higgs boson. Future searches will exploit larger data samples to achieve sensitivity to even smaller production rates. Improvements to these searches are underway that employ reduced lepton momentum thresholds and novel signal vs. background discriminating variables to enhance the sensitivity to models that produce even less energy in the detector. A discovery in these searches could shed light on the nature of dark matter and help resolve the "hierarchy problem," a fundamental theoretical shortcoming of the Standard Model leading to a predicted Higgs boson mass that is some 16 orders of magnitude too large. [18]

Hunting for the superpartner of the top quark

Supersymmetry (SUSY) is one of the most attractive theories extending the Standard Model of particle physics. SUSY would provide a solution to several of the Standard Model's unanswered questions, by more than doubling the number of elementary particles, giving each fermion a bosonic partner and vice versa. In many SUSY models the lightest supersymmetric particle (LSP) constitutes dark matter.

Certain (dubbed "natural") SUSY models may explain the relatively light mass of the Higgs boson. Natural SUSY requires the mass of the supersymmetric partner of the top quark – the top squark – to be less than about a thousand times the mass of a proton. Hunting for the top squark has been a challenge, as top squark events are rare and hidden in the overwhelming Standard Model background. Only by gathering significant amounts of data from LHC proton–proton collisions can ATLAS physicists overcome these odds.

In March 2017, the ATLAS Collaboration presented new results on the search for top squark pair production in a fully hadronic ("0-lepton") channel using the entire available data sample taken at 13 TeV collision energy in 2015 and 2016. In new ATLAS results presented at the LHCP 2017 conference, the search for top squarks has been extended to the "1-lepton" channel. Different top squark decays have been studied all resulting in the LSP and additional Standard Model particles. Events from the "1-lepton" channel are characterised by multiple jets (a collimated spray of particles), one charged electron or muon (a sort of heavy electron), and some "missing energy" from the LSP that interacts weakly only and is thus not directly visible in the ATLAS detector.

This search comes with challenges: if the mass difference of the top squark and the light SUSY particle is close to the mass of the top quark, the event topology of top squark pair events would be very similar to that of top quark pair events. In previous searches in the "1-lepton" channel, the sensitivity to this difference was found to be poor. In this new result, however, machine learning algorithms like Boosted Decision Trees, have been used in this region, leading to substantially improved sensitivity.

The latest ATLAS result (Figure 1) shows no compelling sign of the top squark. The data can be used to constrain SUSY models thus increasing our knowledge of this theory. Exclusion limits on top squark pair production in the top squark and LSP mass plane are summarised in Figure 2 for a simplified SUSY model where the top squark decays directly into the LSP and some Standard Model particles. While the constraints are stringent there is still room for top squarks to hide. [17]

Heavy, short-lived elementary particle could help refine understanding of the universe

It is the heaviest known fundamental particle, for starters. Although 100 million times smaller than an atom of gold, it has roughly the same mass. It also has an extraordinarily short lifetime. In fact, the life of a top quark is so fleeting, scientists can only detect its presence by documenting a signature trail of particles left behind as it decays.

But more so than its quirks, the top quark may hold the key to a deeper understanding of the fate of our universe.

If researchers at Florida Institute of Technology, employing pioneering new methods, are able to determine the top quark's mass at a level of precision as yet unachieved, they will move science closer to understanding whether the universe is stable, as we have long believed to be the case, or unstable.

They are reexamining the mass of the top quark using data collected by the Compact Muon Solenoid (CMS) detector at the Large Hadron Collider (LHC), the world's largest and most powerful particle accelerator based near Geneva, Switzerland.

The top quark doesn't get as much love as another particle, the Higgs boson, which with its famous quantum field is responsible for giving all other particles their mass. But the top quark plays an important role in confirming the validity of the underlying theories of particle physics and the state of our universe.

"Not many people talk about the universe as a quantum mechanical system and particle masses but it turns out the stability of our universe as a quantum system depends on the masses of the top quark and the Higgs boson," said Marc Baarmand, professor of physics and space sciences at Florida Tech who studies the top quark and brought the LHC research to Florida Tech in 2000. "Because the measurements are still not very precise, we are unsure if we are living in a stable or metastable universe.

"The current top quark mass measurements are limited by the systematic uncertainties coming from both data and theory," Baarmand continued. "The new method aims at an alternative measurement with reduced systematic uncertainties."

A more precise measurement of the top quark mass, Baarmand added, "could also help open doors to new physics, and perhaps it could help point us to other new particles in the future."

In addition to their studies of the top quark mass, Florida Tech researchers led by Francisco Yumiceva, associate professor of physics and space sciences, built, calibrated and are operating the hadron calorimeter detector, which measures the energy of particles. Another team, led by Florida Tech's Marcus Hohlmann, professor of physics and space sciences, is developing Gas Electron Multiplier chambers, which precisely measure the trajectories of muons. These researchers and their students study the daughter particles produced by top quarks and Higgs bosons as they decay to better understand how these important particles fit into the large physical framework of the subatomic universe. [16]

Physicists prepare to detect gravitational waves from neutron star collisions

Last February, scientists made the groundbreaking discovery of gravitational waves produced by two colliding black holes. Now researchers are expecting to detect similar gravitational wave signals in the near future from collisions involving neutron stars—for example, the merging of two neutron stars to form a black hole, or the merging of a neutron star and a black hole.

In a new study published in Physical Review Letters, Aleksi Kurkela at CERN and the University of Stavanger in Norway and Aleksi Vuorinen at the University of Helsinki in Finland have developed an improved method of analyzing the ultradense matter called "quark matter" that is thought to exist in the cores of neutron stars.

Their method makes theoretical predictions regarding the properties of neutron star matter that researchers working with the future data will hopefully be able to test.

So far, the best quantitative description of quark matter works only at a temperature of absolute zero. Although this zero-temperature approximation is adequate for describing dormant neutron stars, neutron star collisions would have such drastically higher temperatures that thermal corrections are essential.

In the new study, Kurkela and Vuorinen have accounted for high-temperature effects and incorporated them into the equation of state that describes quark matter, generalizing the equation to relatively small but non-zero temperatures. This modified framework provides a much more accurate description of quark matter that is valid in the hot conditions present in neutron star mergers.

Quark matter

As their name implies, neutron stars are made mostly of neutrons, and like all known matter, neutrons are made of quarks. Usually quarks are tightly bound together in groups of three, but the enormous density and pressure in the core of a neutron star is thought to break the structure of the neutrons, so that the quarks separate and form quark matter. Whereas atoms are the basic constituents of the atomic matter that we're familiar with, the basic constituents of quark matter are quarks (along with gluons that hold the quarks together).

Currently, quark matter is not very well understood, mainly because it does not exist naturally on Earth. Researchers can produce quark-gluon plasma at high-energy particle colliders, such as the Large Hadron Collider (LHC), but it only exists for a fraction of a second before decaying because of the difficulty in maintaining the extreme conditions it requires.

Gravitational waves from neutron stars

An alternative to producing quark matter is to search for it in space. Using techniques similar to those that were recently used to detect gravitational waves from black hole collisions, researchers are currently searching for gravitational waves from neutron star collisions. Detecting the signal of such a collision would provide scientists with a wealth of new information on quark matter.

"The hope is that the gravitational wave signal from a merger of two neutron stars or a neutron star and a black hole would provide detailed information about the structure of neutron stars," Kurkela told Phys.org. "This in turn would enable researchers to infer the equation of state of the matter the stars are composed of, i.e., the thermodynamic properties of nuclear and quark matter."

If experimentally detecting quark matter is difficult, theoretically describing it is equally as challenging. This is because the description involves applying the strong force (which is mediated by the gluons) to the extremely high-energy matter of neutron stars.

"Our goal as particle/nuclear theorists is to predict the equation of state from first principles, i.e., starting from the basic properties of the theory of strong interactions, quantum chromodynamics (QCD)," Vuorinen said. "This is a long and very demanding challenge, but if we are successful, then one day when neutron star observations are accurate enough, our results can be used to interpret the observational data from neutron star mergers, and ultimately tell whether neutron stars have quark matter cores."

The results here also apply to the quark-gluon plasma produced in particle accelerators, which the scientists explain is somewhat different than the quark matter predicted to exist in neutron stars.

"The quark-gluon plasma that is produced in heavy ion collisions can be thought of as a hot but not very dense soup of quarks and gluons, while quark matter is a very dense and cold, essentially solid state, of matter," Kurkela said. "Our work in fact bridges the gap between these two systems, as our result is applicable at all temperatures, unlike any of the previous results."

In the future, the researchers plan to further refine their method to improve its predictions.

"Together with our collaborators both from Europe and the US, we are actively working towards improving the current state-of-the-art results for the zero-temperature equation of state of quark matter," Vuorinen said. "We hope to have the next orders of the so-called weak coupling expansion of the equation of state available still during this year, which will allow a refined prediction of the properties of cold quark matter." [15]

New approach to nuclear structure, freely available

The atomic nucleus is highly complex. This complexity partly stems from the nuclear interactions in atomic nuclei, which induce strong correlations between the elementary particles, or nucleons, that constitute the heart of the atom. The trouble is that understanding this complexity often requires a tremendous amount of computational power. In a new study published in EPJ A, Susanna Liebig from Forschungszentrum Jülich, Germany, and colleagues propose a new approach to nuclear structure calculations. The results are freely available to the nuclear physicists' community so that other groups can perform their own nuclear structure calculations, even if they have only limited computational resources.

The idea outlined in this work is to describe the quantum mechanical states of nuclei in terms of relative coordinates, which makes it possible to describe the correlations between nucleons more easily. This approach also helps to separate out the motion of the centre of mass, thus further reducing the complexity of the problem. To date, most nuclear structure calculations have been performed using single particle basis states, as (in keeping with what is referred to as the Pauli exclusion principle) two identical elementary particles cannot occupy the same basis state—an aspect that is tremendously difficult to address in relative coordinates... Now, in the new work, the authors generate sets of basis states for nucleons in complex nuclei, which feature anti-symmetrical relative coordinates.

The authors introduce an algorithm designed to reflect the anti-symmetrized nature of the nucleon states using standard harmonic oscillator states for the light p-shell nuclei. The states are produced along with their corresponding recoupling coefficients, making it possible to include two- and three-nucleon operators. The study focuses on several p-shell nuclei and examines their dependence on the harmonic oscillator frequency. Subsequently, the authors extract the binding and excitation energies of these nuclei. [14]

Physicists zoom in on gluons' contribution to proton spin

By analyzing the highest-energy proton collisions at the Relativistic Heavy Ion Collider (RHIC), a particle collider at the U.S. Department of Energy's (DOE) Brookhaven National Laboratory, nuclear physicists have gotten a glimpse of how a multitude of gluons that individually carry very little of the protons' overall momentum contribute to the protons' spin. The data described in a recently published paper indicate that these glue-like particles—named for their role in binding the quarks that make up each proton—play a substantial role in determining the intrinsic angular momentum, or spin, of these building blocks of matter.

"These results confirm our suspicion that a lot of the gluons' contribution to proton spin comes from the gluons with relatively low momentum," said Ralf Seidl, a physicist from the RIKEN-BNL Research Center (RBRC) and a member of RHIC's PHENIX collaboration, which published these results. The results also suggest that gluons' overall contribution to spin might be even greater than the contribution from quarks.

Exploring the sources of proton spin is one of the major scientific missions at RHIC, a DOE Office of Science User Facility and the only machine in the world capable of colliding protons with their spins aligned in a chosen direction. Nuclear physicists from around the globe, including many supported by the Japanese RIKEN laboratory, come to RHIC to study these "polarized proton" collisions in an effort to solve the so-called proton spin puzzle. The RBRC was established at Brookhaven in collaboration with RIKEN to support young scientists engaged in this and other relevant research.

The proton spin mystery originated when experiments in the 1980s revealed that a proton's spin—a property that influences these particles' optical, electrical, and magnetic characteristics—does not come solely from its quarks. To tease out the gluons' role, RHIC physicists collide two beams of protons with their spins aligned in the same direction, and then with the polarization of one beam flipped so the spins are "antialigned." The PHENIX detector measures the number of particles called pions that come out of the collision zone perpendicular to the colliding beams under these two conditions. Any difference observed in the production of these pions between the two conditions is an indication of how much the gluons' spins are aligned with, and therefore contribute to, the spin of the proton.

RHIC is the only machine in the world that can collide protons with their spins aligned in a particular direction. Measuring differences in the particles produced when the spins in the two beams are pointing at one another (as shown) vs. when they are pointing in the same direction, colliding "head" to "tail," can help scientists tease out the contribution made by gluons.

Results reported in 2014 indicated that gluons definitely play a significant role, but the uncertainty about the size of their contribution was fairly large. Both the energy of the collisions and the angles at which RHIC's detectors were measuring limited the range of gluons those experiments could explore.

The new data come from collisions at a much higher energy—500 billion electron volts (GeV) as compared to the earlier 200 GeV data.

"This higher collision energy allows us to extend the 'kinematic range' to look at the contributions of gluons that carry a lower fraction of the overall momentum of the proton," said Seidl. "It sounds contradictory at first, but as the collision energy goes up, the 'momentum fraction' of the gluons whose contribution you are measuring goes down."

You can think of it like a microscope, explained John Lajoie, a PHENIX collaborator from Iowa State University. "Going to higher energy allows you to focus on smaller objects. In this case the smaller object is the lower-momentum-fraction gluons."

In the 1980s, scientists discovered that a proton's three valance quarks (red, green, blue) account for only a fraction of the proton's overall spin. New measurements from RHIC's PHENIX experiment reveal that gluons (yellow corkscrews) …more

The data show that these "wimpy" gluons play an outsized role in contributing to proton spin. The reason, the physicists say, is that there are so many of them.

"The density of gluons increases very rapidly for very low momentum fractions," Seidl said.

Using the microscope analogy again, "the more we zoom in, the more 'quantum fluctuations' we can observe," said Lajoie, referring to the whimsical tendency of subatomic particles to split and transform. "Inside the proton, there's a sea of quarks and antiquarks and gluons changing and evolving. When you look with one resolution you see a certain number, but looking closer you can see that some of these particles have split, so there are actually more gluons there."

The measurements of low-momentum-fraction gluon polarization, and these particles' large contribution to overall proton spin, have reduced the uncertainties about the overall size of the gluon contribution to spin somewhat. While the previous results indicated that gluons might contribute about as much as the quarks and antiquarks, the new findings may bring the gluons' total contribution a bit higher.

"Large uncertainties remain and there's room for improvement in these measurements," Seidl said. There are also other ways to look for contributions from even lower-momentum-fraction gluons, including exploring particles emerging from collisions at more "forward" angles. "Extending the momentum fraction range even further to lower values is one of the remaining goals of the RHIC spin program," Seidl said.

It's also one reason nuclear physicists would like to build an electron ion collider (EIC), a machine that would use an electron beam to probe the internal structure of the proton even more directly.

"An EIC would allow us to make numerous, extremely precise measurements across a much wider range of momentum fractions," said Brookhaven physicist Elke Aschenauer, a leader in the spin program at RHIC. "It would be the only facility in the world that could measure the distribution of polarized gluons as a function of their momentum and also their spatial distribution in the proton—like a microscope that resolves even the smallest features very precisely."

A recent report from the U.S. Nuclear Science Advisory Committee ranked an EIC as its top priority for new facility construction once another construction project already underway is complete. So scientists may get their wish of being able to see gluons precisely enough to finally resolve the spin mystery. [13]

More realistic versions of lattice QCD

Under normal conditions, quarks and gluons are confined in the protons and neutrons that make up everyday matter. But at high energy densities—the range accessible at today's particle accelerators—quarks and gluons form a plasma reminiscent of the primordial Universe after the big bang. Understanding how the transition (Fig. 1) from the confined state to this quark-gluon plasma (and vice versa) occurs is a fundamental goal of experiments at the Relativistic Heavy Ion Collider and the Large Hadron Collider, which recreate the plasma by colliding nuclei at ultrarelativistic speeds. Theorists are therefore looking for new ways to study the transition with quantum chromodynamics (QCD), the mathematically challenging theory that describes the strong interaction between quarks. In Physical Review Letters, researchers in the HotQCD Collaboration report an analysis of this phase transition using a formulation of QCD that lends itself to numerical solutions on a computer, called lattice QCD [6]. Their simulations of deconfinement—the first to be performed with a version of lattice QCD that accurately describes the masses and, in particular, the symmetries of the quarks—yield the critical temperature for the transition to occur, and show that it is a smooth crossover, rather than an abrupt change.

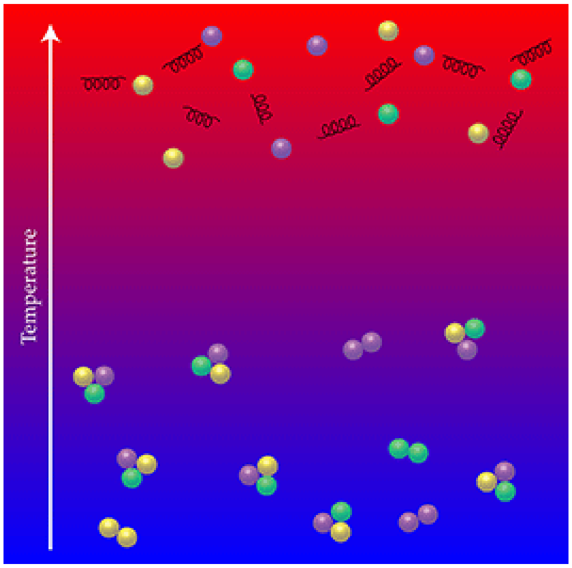


Figure 1. At everyday temperatures, quarks are confined in hadrons (such as protons, neutrons and pions). But at the energy densities accessible at particle accelerators, quarks can become deconfined, forming a quark-gluon plasma—a phase reminiscent of the primordial Universe. Numerical simulations based on lattice quantum chromodynamics are helping physicists understand how the transition from the confined to the deconfined state occurs. [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) $M_p = n^2 M_e$

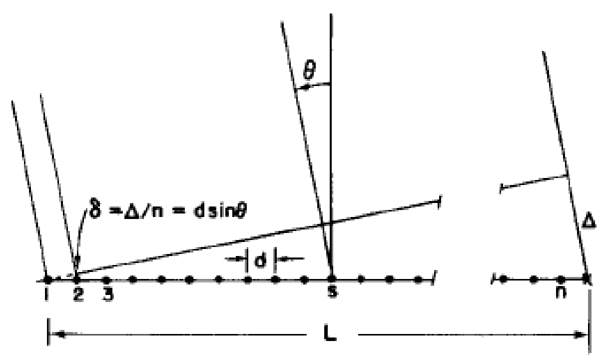


Fig. 30–3. A linear array of *n* equal oscillators, driven with phases $\alpha_s = s\alpha$.

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 θ = m λ

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 θ = 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:

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

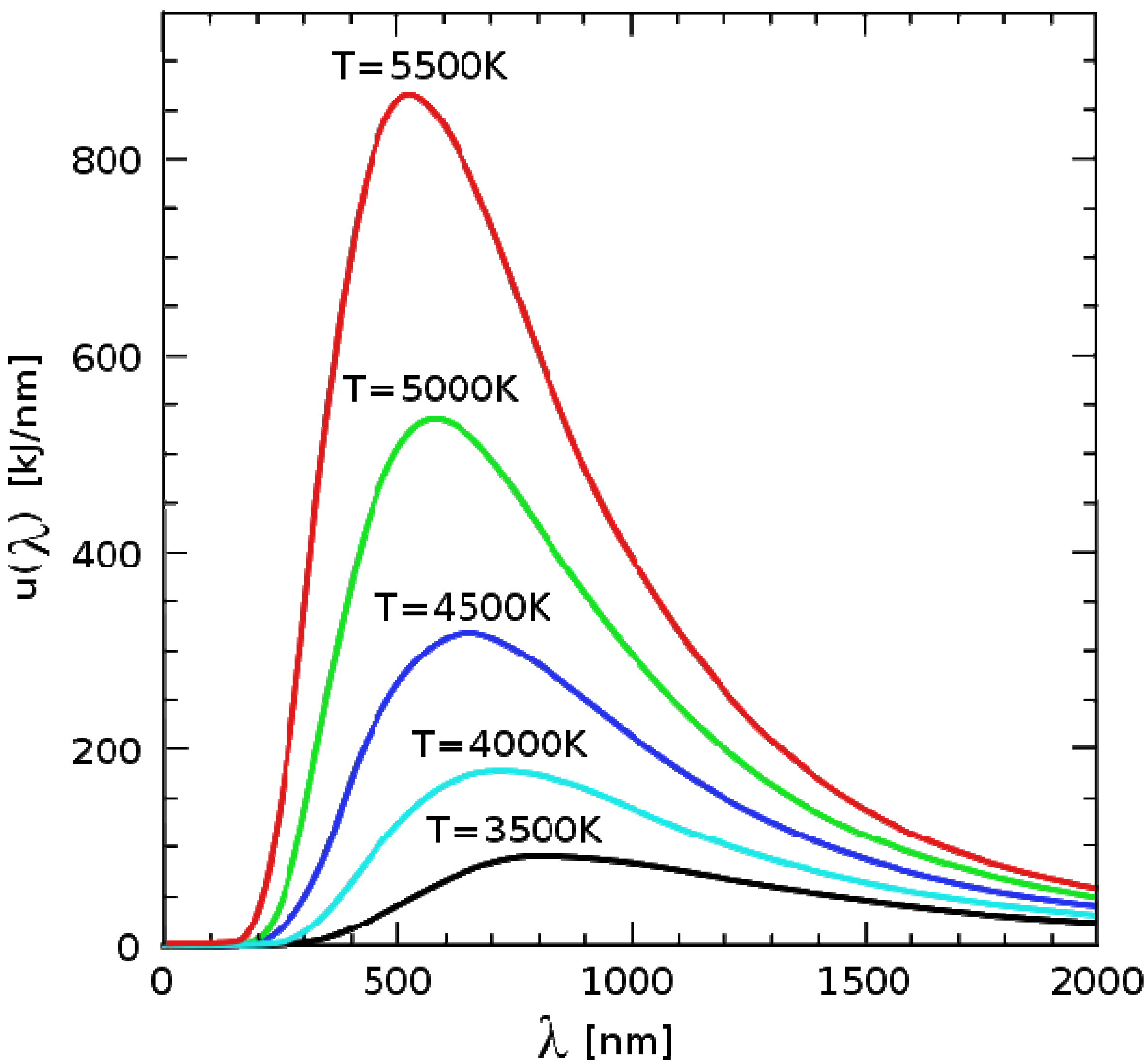


Figure 2. The distribution law for different T temperatures

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 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 $E = hv$ and $E = mc^2$, $m = hv /c^2$ that is the m depends only on the v 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]

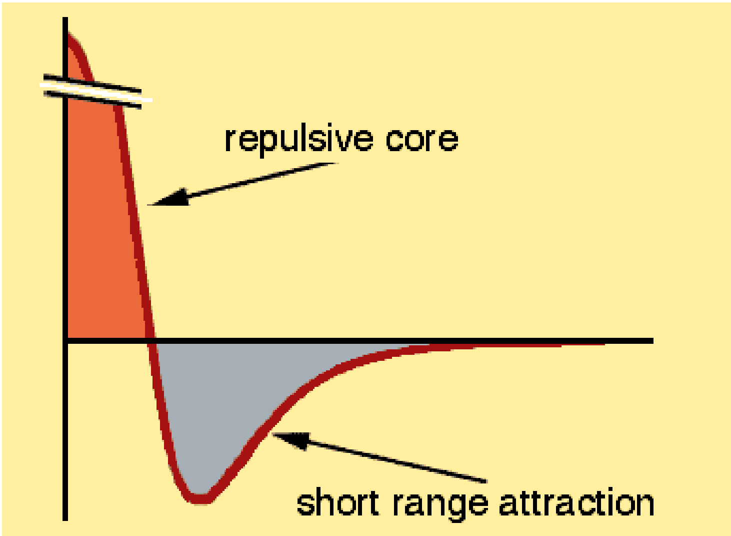
There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a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

More realistic versions of lattice QCD may lead to a better understanding of how quarks formed hadrons in the early Universe.

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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