Lattice QCD for Nuclear Science

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Now, powerful supercomputer simulations of colliding atomic nuclei, conducted by an international team of researchers including a Berkeley Lab physicist, provide new insights about the twisting, whirlpool-like structure of this soup and what's at work inside of it, and also lights a path to how experiments could confirm these characteristics. [10]

The drop of plasma was created in the Large Hadron Collider (LHC). It is made up of two types of subatomic particles: quarks and gluons. Quarks are the building blocks of particles like protons and neutrons, while gluons are in charge of the strong interaction force between quarks. The new quark-gluon plasma is the hottest liquid that has ever been created in a laboratory at 4 trillion C (7 trillion F). Fitting for a plasma like the one at the birth of the universe. [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!

Particle interactions on Titan support the search for new physics discoveries

Nuclear physicists are using the nation's most powerful supercomputer, Titan, at the Oak Ridge Leadership Computing Facility to study particle interactions important to energy production in the sun and stars and to propel the search for new physics discoveries.

Direct calculations of these nuclear processes can contribute new and fundamental information to the fields of high-energy physics, nuclear science, and astrophysics, including how matter formed in the early universe and its relation to dark matter and the large-scale structure of the universe.

The research team using Titan, including principal investigator William Detmold of the Massachusetts Institute of Technology, is calculating proton-proton fusion—a process that powers the sun and other stars in which two protons fuse to form a deuteron—and double beta decay, a rare process which occurs when an unstable nucleus decays by emitting two electrons with or without neutrinos (subatomic particles with near-zero mass).

Although double beta decay with neutrinos has been observed in experiment, the team is focused on neutrinoless double beta decay—a type of double beta decay predicted by theory in which no neutrinos are emitted, only electrons. Yet to be observed, this neutrinoless process is of great interest to physicists because it could lead to new discoveries beyond the current model of particle physics known as the Standard Model.

The Standard Model, a description of all the known subatomic particles and fundamental forces in the universe except for gravity, has held up in experiments time and again. However, the Standard Model is not complete because it cannot fully explain what scientists observe at the cosmic scale.

Based on observations of galaxies, supernova, and other phenomena, researchers estimate that the universe consists of very little ordinary matter (only about 5 percent) and is mostly unseen dark matter that exerts a gravitational pull on ordinary matter (about 25 percent) and dark energy (about 70 percent). Yet scientists do not know what makes up dark matter or in what ways it may interact with ordinary matter other than gravitationally.

To help answer these and other cosmic questions, experiments are being built around the world to probe particle interactions at new scales and energies, and supercomputers are being used to simulate rare or theoretical interactions. By modeling the interactions of simple nuclei, physicists can understand the kind of experiments they need to build and what they may expect from experimental data.

On Titan, Detmold's team used complex lattice quantum chromodynamics (QCD) calculations to predict the reaction rate—the probability that nuclear fusion or decay will occur—of proton-proton fusion and an important part of the theoretical rate of neutrinoless double beta decay.

"We're showing that you can see the bound states of nuclei using quantum chromodynamics," Detmold said. "From there, we're calculating the simplest nuclear processes that happen."

Modeling space-time

Nuclear fusion of hydrogen—the lightest element consisting only of a proton and electron—powers stars for millions to billions of years. Detmold's team calculated the proton-proton fusion cross section on supercomputers because this interaction plays a critical role in solar energy production.

"We can't experimentally probe proton-proton fusion that well," Detmold said. "Even if you take a proton target and irradiate it with a beam of protons, the protons will just scatter, not fuse, so this fusion process is very rare in the laboratory."

In this process, two protons overcome their electromagnetic repulsion between like charges and interact through the short-range, subatomic force known as the weak force.

Lattice QCD calculations represent how the fundamental particles that make up protons—quarks and gluons—interact in the volume of space-time in which proton-proton fusion occurs. Quarks are the smallest known constituents of matter, and gluons are the force-carrying particles that bind them. Named for the 4-D grid (the lattice) that represents space-time and the unique "color charge" (chromo), which refers to how quarks and gluons combine rather than to actual colors, lattice QCD calculations are intensive computations that can require supercomputing power.

Efficiently using Titan's GPU-accelerated architecture, Detmold's team used the Chroma lattice QCD library (developed primarily by Robert Edwards and Balint Joò of Thomas Jefferson National Accelerator Facility) with a new algorithm to include weak interactions important to proton-proton fusion and QUDA, a lattice QCD library for GPUs (developed primarily by Kate Clark of NVIDIA). The calculations generated more than 1,000 snapshots of the 4-D lattice with 10 million points of calculation per snapshot.

"These are the first QCD calculations of the proton-proton fusion rate," Detmold said.

Researchers used the same lattice QCD algorithms to calculate another weak interaction process, tritium beta decay, which has been studied experimentally and was used to verify the calculations.

Narrowing the search

Researchers also calculated subprocesses that contribute to double beta decay rates, including theoretical rates for neutrinoless double beta decay.

A rare particle event, double beta decay was first predicted in 1935 but not observed in experiments until the 1980s. This type of decay can occur naturally when two neutrons decay into two protons inside a nucleus, emitting two electrons and two neutrinos in the process. Although rare, double beta decay occurs in some isotopes of heavy elements as a way for the nucleus to stabilize its number of protons and neutrons.

Neutrinoless double beta decay, also predicted over half a century ago, has never been observed. However, this potential process has gained much more significance in recent years since physicists discovered that neutrinos have a small mass. Because the neutrino has a neutral charge, it is theoretically possible that it is its own antiparticle—a particle of the same mass but opposite charge. Antiparticles exist in nature and have been created and observed in experiment, but matter particles are much more dominant in nature.

A particle that is its own antiparticle, known as a Majorana particle, could help explain the mechanism by which matter took precedence over antimatter in the universe, which is one of the great outstanding questions in cosmology.

Many experiments across the globe are trying to observe neutrinoless double beta decay, which would confirm the existence of a Majorana neutrino. Such a discovery would, for the first time, provide an unambiguous signature of the violation of lepton number conservation—the principle that describes balance between certain types of matter particles and their antiparticles.

Experiments such as the MAJORANA Demonstrator at the Sanford Underground Research Facility cool heavy elements in underground laboratories to temperatures colder than empty space. In their remote locations with heavy shielding, neutrino detectors like the MAJORANA Demonstrator are enabling scientists to narrow their search for rare neutrino interactions.

Because neutrinoless double beta decay is theoretical and, if real, still very rare, researchers must make extremely refined predictions of its reaction rate. The smaller the reaction rate, the less likely experiments will be able to capture the process and the bigger the experimental detector needs to be. The Titan calculations help researchers understand potential decay rates.

"Ultimately, what we are trying to determine is how likely an experiment of a given size is going to be able to see this process, so we need to know the reaction rate," Detmold said.

Current neutrino experiments are pilot scale, using tens of kilograms of a heavy element medium (germanium crystals in the case of MAJORANA). Future detectors could be built at ton scale, and it is important to know that such an experiment would be sensitive enough to see neutrinoless double beta decay if it exists.

The team's calculations of double beta decay on Titan provide the kind of theoretical support experimentalists need to develop experiments and analyze data.

But proton-proton fusion and neutrinoless double beta decay are only two nuclear processes of many that can be gateways to new discoveries in physics.

With next-generation systems like the OLCF's Summit supercomputer, which will come online later this year, these calculations will be taken to a new level of accuracy, and researchers can begin to study the decays and interactions of more complex nuclei.

"Now that we've shown that we can control these few nucleon processes, we can start calculating more complicated processes," Detmold said. [12]

General approach for the solution of lattice gauge theories

It is not the daily occurrence that physicists from entirely different fields closely work together. However, in theoretical physics a general ansatz can offer solutions for a large variety of problems. A team of scientists from the Theory Division of Professor Ignacio Cirac at the Max Planck Institute of Quantum Optics has now for a couple of years collaborated with theorists from the field of particle physics, in order to find a new and simplified formulation of lattice gauge theories. (*Physical Review X* 7, 28 November 2017)

Gauge theories play a central role in many areas of physics. They are, for instance, the foundation of the theoretical description of the standard model of particle physics that has been developed in the 1970ies. In this theory, both the elementary particles and the forces that act between them are described in terms of fields, whereby gauge invariance has to be ensured: different configurations of these fields, which can be transformed into each other by generalized local rotations—so-called gauge transformations—should have no impact on related observable quantities such as the mass or charge of a particle or the strength of the interacting force. In the theoretical description, this local symmetry is ensured by introducing additional degrees of freedom in form of a gauge field. These degrees of freedom, however, are often partially redundant, rendering gauge theories very difficult to solve.

"It is our goal to find a formulation, i.e. the Hamiltonian of the system, which minimizes the complexity of its description. As a prototype, we take a special gauge system with only one dimension in space and time," explains Dr. Mari Carmen Bañuls, a senior scientist in the Theory Division of Professor Ignacio Cirac. For the simple case of one temporal and one spatial dimension, the gauge degrees of freedom are not truly independent and can in principle be integrated out, so it should be possible to find a description that does not require additional gauge degrees of freedom. At first sight, this makes these systems simpler to work with. "However, this approach has so far only been successful for Abelian gauge theories, the most simple case, in which gauge fields only interact with matter fields and not with themselves," Dr. Bañuls elaborates. "For non-Abelian theories like the ones that arise in the standard model the self-interaction of the gauge fields makes things much more complicated."

A fundamental tool for the numerical study of gauge models is lattice gauge theory. Here, the space-time continuum is approximated by a lattice of discrete points, still ensuring gauge invariance. Based on a lattice formulation the scientists have developed a new formulation of a non-Abelian SU(2) gauge theory in which the gauge degrees of freedom are integrated out. "This formulation is independent of the technique that is used to calculate the energy eigenstates of the systems. It can be used for any numerical or analytical method," Dr. Stefan Kühn emphasizes who has worked on this topic for his doctoral thesis and is at present postdoc scientist at the Perimeter Institute for Theoretical Physics in Waterloo (Ontario, Canada). "However, we found out, that this formulation is especially well suited to solve the lattice gauge model with tensor networks."

The method of tensor networks has originally been developed by the MPQ scientists for the description of quantum many-body-systems in the context of quantum information theory. "Compared to other methods, tensor networks offer the advantage of providing information about the entanglement structure of the system," Mari Carmen Bañuls points out. "The direct access to the quantum correlations in the system offers new possibilities to characterize lattice gauge theories." And Stefan Kühn summarizes the versatility of the new method. "On the one hand, our formulation of a low-dimensional gauge theory makes it easier to calculate and predict certain phenomena in particle physics. On the other hand, it might be suited to design quantum simulators for applications in quantum computing." [11]

Simulations show swirling rings, whirlpool-like structure in subatomic 'soup'

At its start, the universe was a superhot melting pot that very briefly served up a particle soup resembling a "perfect," frictionless fluid. Scientists have recreated this "soup," known as quark-gluon plasma, in high-energy nuclear collisions to better understand our universe's origins and the nature of matter itself. The physics can also be relevant to neutron stars, which are the extraordinarily dense cores of collapsed stars.

Now, powerful supercomputer simulations of colliding atomic nuclei, conducted by an international team of researchers including a Berkeley Lab physicist, provide new insights about the twisting, whirlpool-like structure of this soup and what's at work inside of it, and also lights a path to how experiments could confirm these characteristics. The work is published in the Nov. 1 edition of Physical Review Letters.

Matter, deconstructed

This soup contains the deconstructed ingredients of matter, namely fundamental particles known as quarks and other particles called gluons that typically bind quarks to form other particles, such as the protons and neutrons found at the cores of atoms. In this exotic plasma state—which can reach trillions of degrees Fahrenheit, hundreds of thousands of times hotter than the sun's core—protons and neutrons melt, freeing quarks and gluons from their usual confines at the center of atoms.

These record-high temperatures have been achieved by colliding gold nuclei at Brookhaven National
Laboratory's RHIC (Relativistic Heavy Ion Collider), for example, and lead nuclei at CERN's LHC (Large Hadron Collider). Experiments at RHIC discovered in 2005 that quark-gluon plasma behaves like a fluid. In addition to gold nuclei, RHIC has also been used to collide protons, copper and uranium. The LHC began conducting heavy-ion experiments in 2014, and has confirmed that the quark-gluon plasma behaves like a fluid.

There remain many mysteries about the inner workings of this short-lived plasma state, which may only have existed for millionths of a second in the newborn universe, and nuclear physicists are using a blend of theory, simulations and experiments to glean new details about this subatomic soup.

Surprising complexity in plasma structure

"In our sophisticated simulations, we found that there is much more structure to this plasma than we realized," said Xin-Nian Wang, a theorist in the Nuclear Science Division at Berkeley Lab who has worked for years on the physics of high-energy nuclear collisions.

When plotted out in two dimensions, the simulations found that slightly off-center collisions of heavy nuclei produce a wobbling and expanding fluid, Wang said, with local rotation that is twisted in a corkscrew-like fashion.

This corkscrew character relates to the properties of the colliding nuclei that created the plasma, which the simulation showed expanding along—and perpendicular to—the beam direction. Like spinning a coin by flicking it with your finger, the simulations showed that the angular momentum properties of the colliding nuclei can transfer spin properties to the quark gluon plasma in the form of swirling, ring-like structures known as vortices.

The simulations showed two of these doughnut-shaped vortices—each with a right-handed orientation around each direction of the separate beams of the colliding nuclei—and also many pairs of oppositely oriented vortices along the longest dimension of the plasma. These doughnut-shaped features are analogous to swirling smoke rings and are a common feature in classical studies of fluids, a field known as hydrodynamics.

The simulations also revealed a patterned outward flow from hot spots in the plasma that resemble the spokes of a wheel. The time scale covered in the simulation was infinitesimally small, Wang said, roughly the amount of time it takes light to travel the distance of 10-20 protons. During this time the wobbling fluid explodes like a fireball, spurting the particle soup outward from its middle more rapidly than from its top.

Any new understanding of quark-gluon plasma properties should be helpful in interpreting data from nuclei-colliding experiments, Wang said, noting that the emergence of several localized doughnutlike structures in the simulations was "completely unexpected."

Unraveling a mystery

"We can think about this as opening a completely new window of looking at quark-gluon plasmas, and how to study them," he said. "Hopefully this will provide another gateway into understanding why this quark-gluon fluid is such a perfect fluid—the nature of why this is so is still a puzzle. This work will benefit not only theory, but also experiments."

The simulations provide more evidence that the quark-gluon plasma behaves like a fluid, and not a gas as had once been theorized. "The only way you can describe this is to have a very small viscosity," or barely any friction, a characteristic of a so-called 'perfect fluid' or 'fundamental fluid,'" Wang said. But unlike a familiar fluid like water, the simulation focuses on a fluid state hundreds of times smaller than a water molecule.

Michael Lisa, a physics professor at Ohio State University who is part of the collaboration supporting the Solenoidal Tracker at RHIC (STAR), said the so-called vorticity or "swirl structure" of this plasma has never been measured experimentally, though this latest theoretical work may help to home in on it. STAR is designed to study the formation and characteristics of the quark-gluon plasma.

"Wang and his collaborators have developed a sophisticated, state-of-the-art hydrodynamic model of the quark-gluon plasma and have identified swirling structures that vary within the fluid itself," he said. "Even more useful is the fact that they propose a method to measure these structures in the laboratory."

Lisa also said there is ongoing analysis work to confirm the simulation's findings in data from experiments at RHIC and the LHC. "It is precisely innovations like this, where theory and experiment collaborate to explore new phenomena, that hold the greatest hope for greater insight into the quark-gluon plasma," he said.

"Many tools have been used to probe the inner working mechanics and symmetry properties of this unique matter," said Zhangbu Xu, a spokesperson for the STAR collaboration and a staff scientist at Brookhaven National Laboratory. He also said that preliminary results from STAR also suggest some spinning motion in the fluid, and the simulation work "adds a new dimension" to this possibility. [10]

Physicists Recreate Substance Similar To The Plasma Believed To Have Existed At The Very Beginning Of The Universe

The first seconds of the universe were filled with a boiling, chaotic inferno. It was packed with a dense plasma: a soup-like fire, made up of some of the tiniest particles in the universe. Unbelievably, physicists have recreated a substance that they think is very similar to this early universe plasma. Albeit, just the tiniest drop.

The drop of plasma was created in the Large Hadron Collider (LHC). It is made up of two types of subatomic particles: quarks and gluons. Quarks are the building blocks of particles like protons and neutrons, while gluons are in charge of the strong interaction force between quarks. The new quarkgluon plasma is the hottest liquid that has ever been created in a laboratory at 4 trillionoC (7 trillionoF). Fitting for a plasma like the one at the birth of the universe.

The plasma was created after a collision between a proton and a lead nucleus. The physicists had always thought that this collision wouldn't produce enough particles (around 1,000) to create a plasma. A collision between two lead nuclei, for comparison, is known to produce plasma but creates twenty times more particles (around 25,000) following collision. However, the results defied their expectations.

“Before the CMS experimental results, it had been thought the medium created in a proton on lead collisions would be too small to create a quark-gluon plasma,” said Quan Wang, a physicist from Kansas University (KU), in a statement. "The analysis presented in this paper indicates, contrary to expectations, a quark-gluon plasma can be created in very asymmetric proton on lead collisions."

“This is the first paper that clearly shows multiple particles are correlated to each other in protonlead collisions, similar to what is observed in lead-lead collisions where quark-gluon plasma is produced,” added Yen-Jie Lee, from the Michigan Institute of Technology (MIT). “This is probably the first evidence that the smallest droplet of quark-gluon plasma is produced in proton-lead collisions.”

This new research looks at particle physics with a fresh perspective. Instead of counting individual numbers of particles, the plasma forces physicists to look at the behavior of a volume of particles.

There is also speculation that this plasma replicates the conditions of the early universe. “It’s believed to correspond to the state of the universe shortly after the Big Bang,” Wang continued. This plasma is different to other quark-gluon plasma that have been made before now. The interactions in this plasma are extremely strong, which distinguishes it from other plasmas which interact infrequently (like gas particles). This is what makes the researchers think it might be similar to an early universe plasma.

“While we believe the state of the universe about a microsecond after the Big Bang consisted of a quark-gluon plasma, there is still much that we don't fully understand about the properties of quarkgluon plasma.” [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) $I = I_0 \sin^2 n\ \varphi/2 \ / \ \sin^2 \varphi/2$

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

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

This gives us the idea of

(3) $M_p = n^2 M_e$

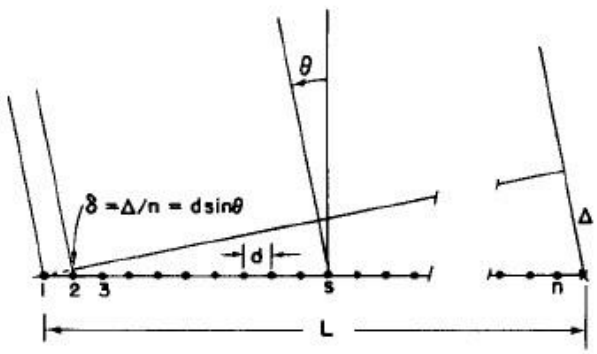


Fig. 30–3. A linear array of *n* equal oscillators, driven with phases $\alpha_s = s\alpha$.

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 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:

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

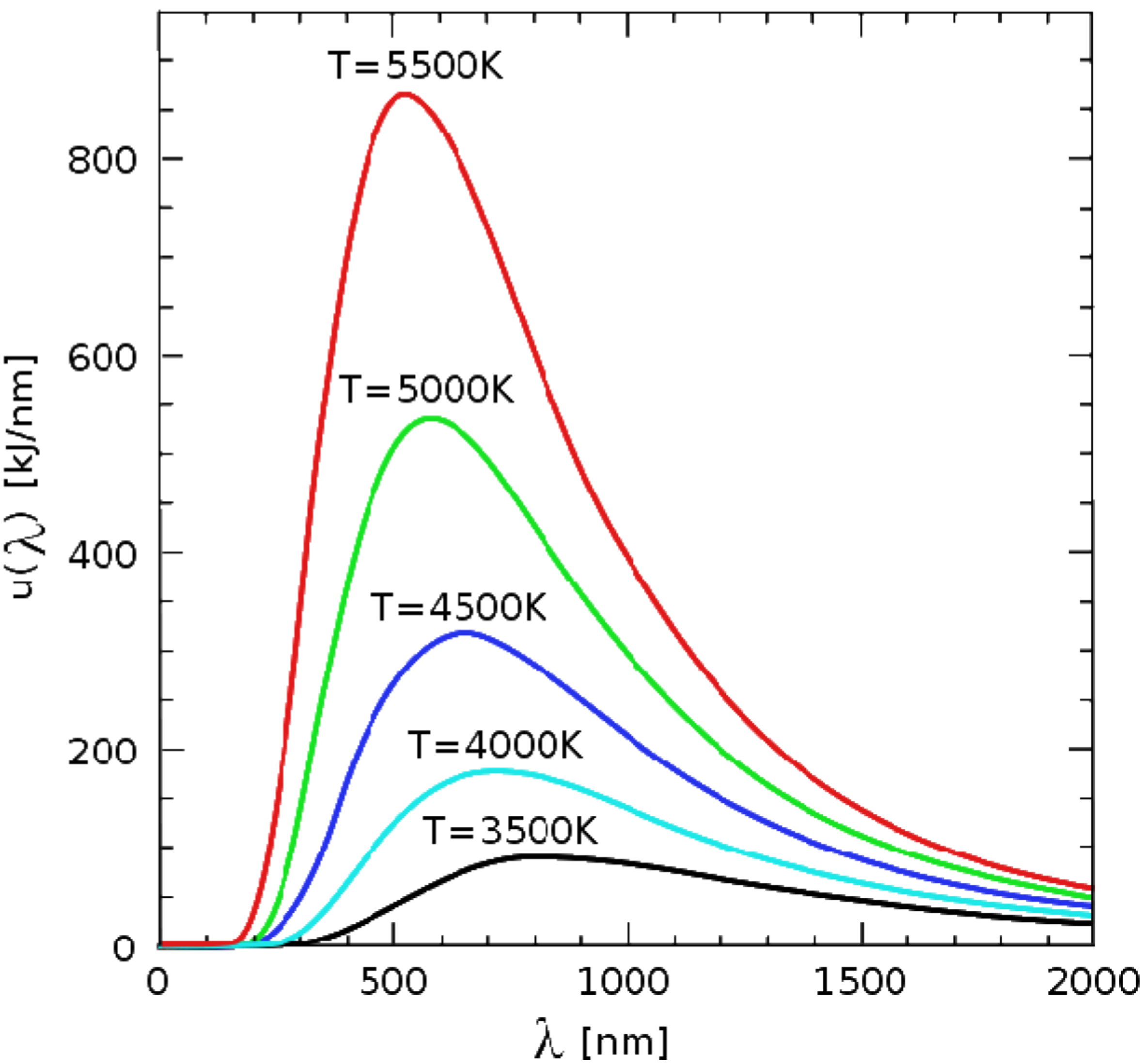


Figure 2. The distribution law for different T temperatures

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 λ_{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]

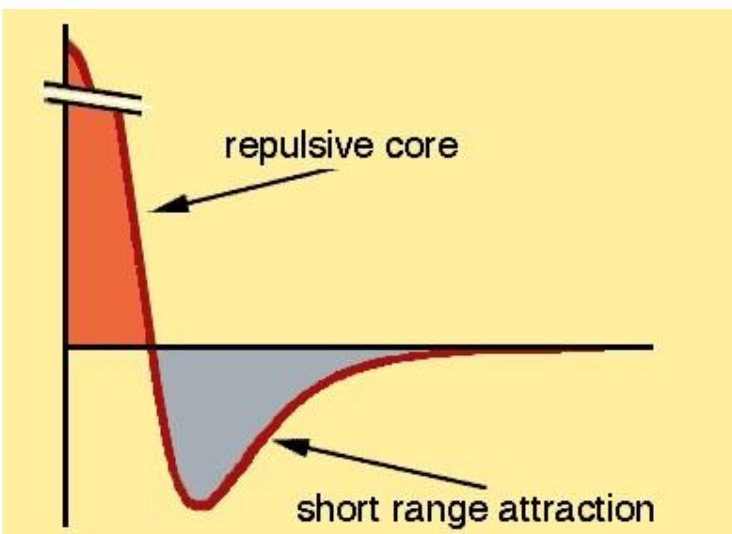
There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a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

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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