Quantum Friction Modeling

Theoretical chemists at Princeton University have pioneered a strategy for modeling quantum friction, or how a particle's environment drags on it, a vexing problem in quantum mechanics since the birth of the field. The study was published in the Journal of Physical Chemistry Letters. [11]

Protons can tunnel in solutions and at temperatures above the boiling point of water, found scientists from the Institute of Physical Chemistry of the Polish Academy of Sciences in Warsaw. [10]

An international team of scientists studying ultrafast physics have solved a mystery of quantum mechanics, and found that quantum tunneling is an instantaneous process. The new theory could lead to faster and smaller electronic components, for which quantum tunneling is a significant factor. It will also lead to a better understanding of diverse areas such as electron microscopy, nuclear fusion and DNA mutations. [9]

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

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Preface

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

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

Theorists smooth the way to modeling quantum friction

Theoretical chemists at Princeton University have pioneered a strategy for modeling quantum friction, or how a particle's environment drags on it, a vexing problem in quantum mechanics since the birth of the field. The study was published in the Journal of Physical Chemistry Letters.

"It was truly a most challenging research project in terms of technical details and the need to draw upon new ideas," said Denys Bondar, a research scholar in the Rabitz lab and corresponding author on the work.

Quantum friction may operate at the smallest scale, but its consequences can be observed in everyday life. For example, when fluorescent molecules are excited by light, it's because of quantum friction that the atoms are returned to rest, releasing photons that we see as fluorescence. Realistically modeling this phenomenon has stumped scientists for almost a century and recently has gained even more attention due to its relevance to quantum computing.

"The reason why this problem couldn't be solved is that everyone was looking at it through a certain lens," Bondar said. Previous models attempted to describe quantum friction by considering the quantum system as interacting with a surrounding, larger system. This larger system presents an impossible amount of calculations, so in order to simplify the equations to the pertinent interactions, scientists introduced numerous approximations.

These approximations led to numerous different models that could each only satisfy one or the other of two critical requirements. In particular, they could either produce useful observations about the system, or they could obey the Heisenberg Uncertainty Principle, which states that there is a fundamental limit to the precision with which a particle's position and momentum can be simultaneous measured. Even famed physicist Werner Heisenberg's attempt to derive an equation for quantum friction was incompatible with his own uncertainty principle.

The researchers' approach, called operational dynamic modeling (ODM) and introduced in 2012 by the Rabitz group, led to the first model for quantum friction to satisfy both demands. "To succeed with the problem, we had to literally rethink the physics involved, not merely mathematically but conceptually," Bondar said.

Bondar and his colleagues focused on the two ultimate requirements for their model—that it should obey the Heisenberg principle and produce real observations—and worked backwards to create the proper model.

"Rather than starting with approximations, Denys and the team built in the proper physics in the beginning," said Herschel Rabitz, the Charles Phelps Smyth '16 *17 Professor of Chemistry and co-author on the paper. "The model is built on physical and mathematical truisms that must hold. This distinct approach creates a new rigorous and practical formulation for quantum friction," he said.

The research team included research scholar Renan Cabrera and Ph.D. student Andre Campos as well as Shaul Mukamel, Professor of Chemistry at the University of California, Irvine.

Their model opens a way forward to understand not only quantum friction but other dissipative phenomena as well. The researchers are interested in exploring the means to manipulate these forces to their advantage. Other theorists are rapidly taking up the new paradigm of operational dynamic modeling, Rabitz said.

Reflecting on how they arrived at such a novel approach, Bondar recalled the unique circumstances under which he first started working on this problem. After he received the offer to work at Princeton, Bondar spent four months awaiting a US work visa (he is a citizen of the Ukraine) and pondering fundamental physics questions. It was during this time that he first thought of this strategy. "The idea was born out of bureaucracy, but it seems to be holding up," Bondar said. [11]

Exotic quantum effects can govern the chemistry around us

Protons can tunnel in solutions and at temperatures above the boiling point of water, found scientists from the Institute of Physical Chemistry of the Polish Academy of Sciences in Warsaw.

Objects of the quantum world have a concealed and cold-blooded nature—they usually behave in a quantum manner only when they are significantly cooled and isolated from the environment. Experiments carried out by chemists and physicists from Warsaw have changed this simple picture. It turns out that not only does one of the most interesting quantum effects occur at room temperature and higher, but it plays a dominant role in the course of chemical reactions in solutions.

We generally derive our experimental knowledge of quantum phenomena from experiments carried out using sophisticated equipment under exotic conditions: at extremely low temperatures and in a vacuum, isolating quantum objects from the disturbing influence of the environment. Scientists from the Institute of Physical Chemistry of the Polish Academy of Sciences (IPC PAS) in Warsaw, led by Prof. Jacek Waluk and Prof. Czeslaw Radzewicz's group from the Faculty of Physics, University of

Warsaw (FUW), have just shown that one of the most spectacular quantum phenomena—quantum tunneling—takes place even at temperatures above the boiling point of water. However, what is particularly surprising is the fact that the observed effect applies to hydrogen nuclei, which tunnel in particles floating in solution. The measurements leave no doubt that in conditions typical for our environment, tunneling turns out to be the main factor responsible for the chemical reaction.

"For some time, chemists have been getting used to the idea that electrons in molecules can tunnel. We have shown that in the molecule, it is also possible for protons—that is, nuclei of hydrogen atoms—to tunnel. So we have proof that a basic chemical reaction can occur as a result of tunneling in solution and at room temperature or higher," explains Prof. Waluk.

In their experiments, the Warsaw researchers studied single molecules of porphycene ($C_{20}H_{14}N_4$), an isomer of porphyrin. Compounds belonging to this group occur naturally, for example in human blood, where they are involved in the transport of oxygen. Their molecules are in the form of planar carbon rings with hydrogen atoms outside and four nitrogen atoms inside, arranged at the corners of a tetragon. In the space surrounded by nitrogen atoms there are two protons. These protons can move between the nitrogen atoms. The open question was whether they do so by moving classically or by tunneling.

Tunneling is a consequence of the probabilistic nature of quantum objects. In the classical world known to us from everyday life, an object will always with total probability be in one place, and therefore with zero probability be in all others. Not so in the quantum world. When nothing disturbs the state of an elementary particle, atom or a small group of them, the probability of the existence of a quantum object dissolves in space. This phenomenon leads to spectacular effects.

When a man wants to surmount a wall, he has to climb it—that is, he has to increase his gravitational energy until it becomes greater than the potential barrier set by the wall. Meanwhile, the indeterminacy of the quantum object means that it can be found on the other side of the barrier, without increasing its energy—simply 'passing through.' The effect occurs much faster than ordinary transfer in space and with a probability that is greater the smaller the distance over which the object tunnels. By studying the times of the proton's jumps, it can be determined if they have moved classically or if they have tunneled.

"Reality is less clear-cut. The higher our proton climbs the energy ladder of porphycene, the smaller the width of the barrier to overcome. Tunneling then becomes increasingly likely. So everything indicates that before the proton has time to climb to an energy level allowing it to classically overcome the potential barrier, it has usually tunneled anyway," explains Prof. Waluk.

Climbing the potential barrier is not simple. When we supply the protons in porphycene with energy, we also induce vibrations in the molecule itself. It turns out that among 108 possible modes of vibration in a molecule of porphycene, some increase the probability of tunneling and others decrease it. The Warsaw-based researchers, funded by grants from the Polish National Science Centre, determined the rate constants of chemical reactions involving porphycene in the temperature range from 20 to 400 Kelvin for proton jumps occurring in the lowest energy state of the molecule, and in one of the excited vibrational states, promoting tunneling. The timing of proton jumps between the nitrogen atoms were thus obtained. Experiments conducted on sets of cold, isolated particles suggested times of a few picoseconds (a millionth of one millionth of a second), and such times were observed in experiments in Warsaw, led by Dr. Piotr Fita and Ph.D. student Piotr Ciacka from the FUW. Measurements show that not only does tunneling occur in porphycene, but it is responsible, even at room temperature, for at least 80 percent of the proton jumps in the centres of the molecules.

The dominant role of tunneling in the course of a chemical reaction and its dependence on the type of vibration of the molecule is a means to incredibly precise control of the course of chemical reactions. This sort of chemistry, known as mode-selective chemistry, has been demonstrated previously, but at a very low temperature. The discovery of the researchers from the IPC PAS and the FUW suggests that in the future, it will be possible to accurately control reactions taking place under conditions typical for our environment. Chemical molecules floating in solution, previously excited in a manner that enhances their reactivity, could be introduced into a state of oscillation that significantly reduces their reactivity (or vice versa). A specific reaction, perhaps one of many taking place in the solution, could then be switched on and off on demand, by small changes in the amount of energy supplied to the molecules of a selected compound.

"The tunneling of protons in molecules of porphycene in solution is spectacular proof that even at room temperature and in a dense environment, a purely quantum effect can rule the course of a chemical reaction. But this is not the end of the surprises. We have a reasonable suspicion that one more exotic quantum phenomenon is involved in the movements of the two protons in porphycene, always jumping together. The world of chemistry around us would then be even more interesting," says Prof. Waluk. [10]

Physicists solve quantum tunneling mystery

At very small scales quantum physics shows that particles such as electrons have wave-like properties – their exact position is not well defined. This means they can occasionally sneak through apparently impenetrable barriers, a phenomenon called quantum tunneling.

Quantum tunneling plays a role in a number of phenomena, such as nuclear fusion in the sun, scanning tunneling microscopy, and flash memory for computers.

However, the leakage of particles also limits the miniaturisation of electronic components.

Professor Kheifets and Dr. Igor Ivanov, from the ANU Research School of Physics and Engineering, are members of a team which studied ultrafast experiments at the attosecond scale (10-18 seconds), a field that has developed in the last 15 years.

Until their work, a number of attosecond phenomena could not be adequately explained, such as the time delay when a photon ionised an atom.

"At that timescale the time an electron takes to quantum tunnel out of an atom was thought to be significant. But the mathematics says the time during tunneling is imaginary – a complex number – which we realised meant it must be an instantaneous process," said Professor Kheifets.

"A very interesting paradox arises, because electron velocity during tunneling may become greater than the speed of light. However, this does not contradict the special theory of relativity, as the tunneling velocity is also imaginary" said Dr Ivanov, who recently took up a position at the Center for Relativistic Laser Science in Korea.

The team's calculations, which were made using the Raijin supercomputer, revealed that the delay in photoionisation originates not from quantum tunneling but from the electric field of the nucleus attracting the escaping electron.

The results give an accurate calibration for future attosecond-scale research, said Professor Kheifets.

"It's a good reference point for future experiments, such as studying proteins unfolding, or speeding up electrons in microchips," he said. [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) $I = I_0 \sin^2 n\,\phi/2 \,\mathbf{/}\, \sin^2 \phi/2$

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

(2) $I = n^2 I_0$

This gives us the idea of

(3) $M_p = n^2 M_e$

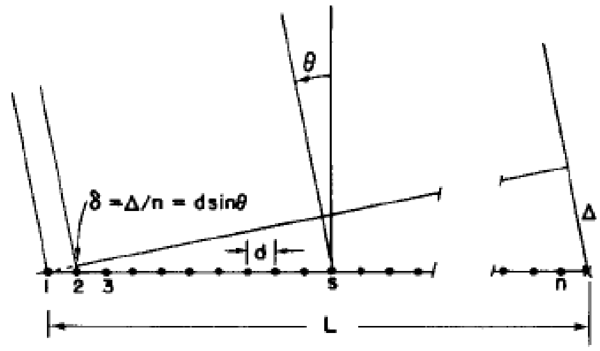


Fig. 30–3. A linear array of n equal oscillators, driven with phases $\alpha_s = s\alpha$.

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:

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

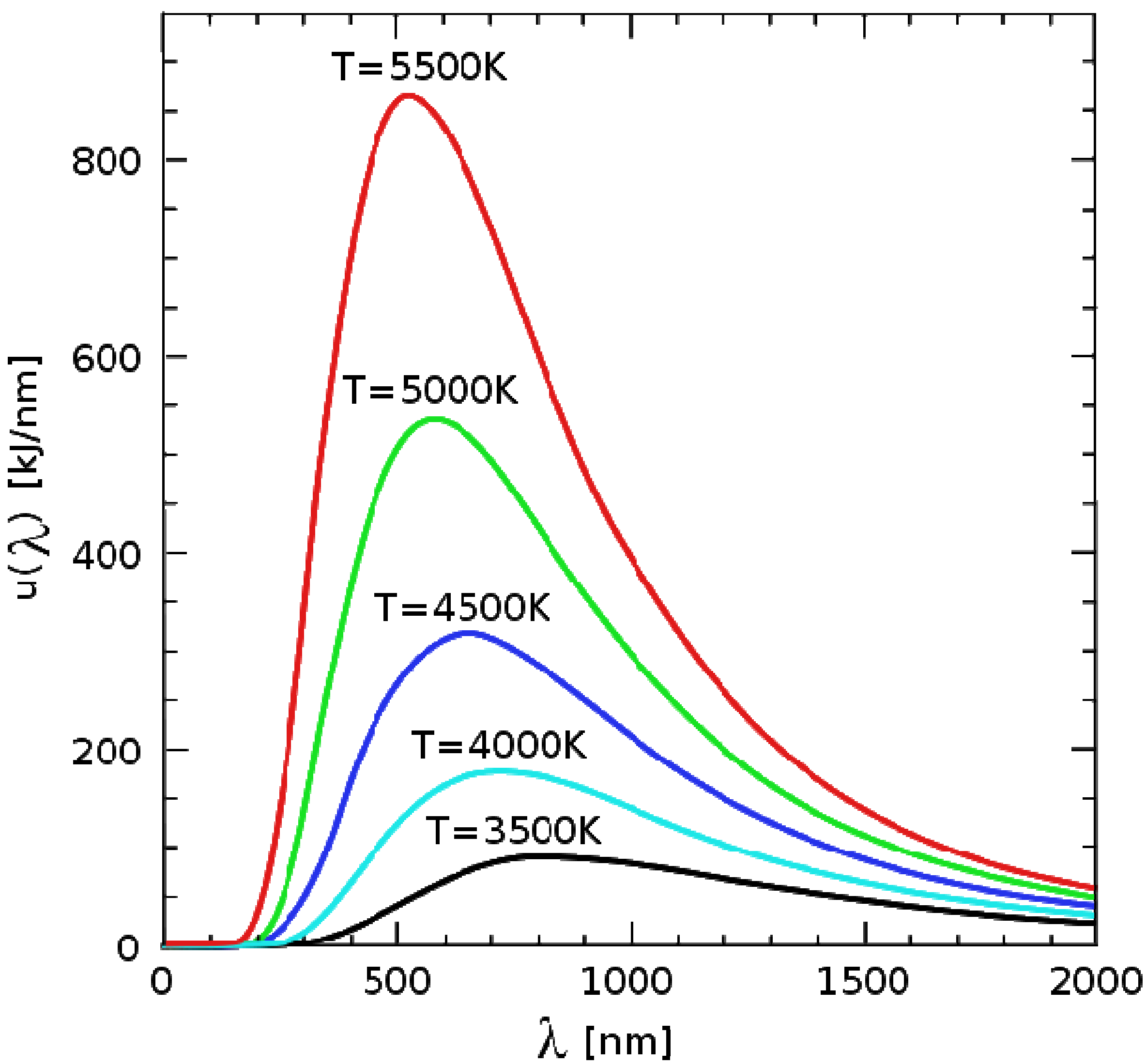


Figure 2. The distribution law for different T temperatures

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 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]

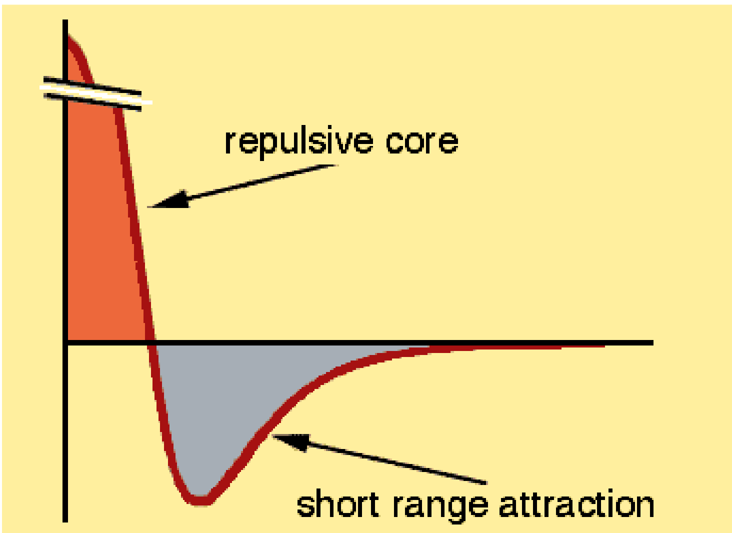
There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a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

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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