Quantum Simulations of Nuclear Physics

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Is entanglement really necessary for describing the physical world, or is it possible to have some post-quantum theory without entanglement? [10]

A trio of scientists who defied Einstein by proving the nonlocal nature of quantum entanglement will be honoured with the John Stewart Bell Prize from the University of Toronto (U of T). [9]

While physicists are continually looking for ways to unify the theory of relativity, which describes large-scale phenomena, with quantum theory, which describes small-scale phenomena, computer scientists are searching for technologies to build the quantum computer using Quantum Information.

In August 2013, the achievement of "fully deterministic" quantum teleportation, using a hybrid technique, was reported. On 29 May 2014, scientists announced a reliable way of transferring data by quantum teleportation. Quantum teleportation of data had been done before but with highly unreliable methods.

The accelerating electrons explain not only the Maxwell Equations and the Special Relativity, but the Heisenberg Uncertainty Relation, the Wave-Particle Duality and the electron's spin also, building the Bridge between the Classical and Quantum Theories.

The Planck Distribution Law of the electromagnetic oscillators explains the electron/proton mass rate and the Weak and Strong Interactions by the diffraction patterns. The Weak Interaction changes the diffraction patterns by moving the electric charge from one side to the other side of the diffraction pattern, which violates the CP and Time reversal symmetry.

The diffraction patterns and the locality of the self-maintaining electromagnetic potential explains also the Quantum Entanglement, giving it as a natural part of the Relativistic Quantum Theory and making possible to build the Quantum Computer with the help of Quantum Information.

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Author: George Rajna

Preface

While physicists are continually looking for ways to unify the theory of relativity, which describes large-scale phenomena, with quantum theory, which describes small-scale phenomena, computer scientists are searching for technologies to build the quantum computer.

Australian engineers detect in real-time the quantum spin properties of a pair of atoms inside a silicon chip, and disclose new method to perform quantum logic operations between two atoms. [5]

Quantum entanglement is a physical phenomenon that occurs when pairs or groups of particles are generated or interact in ways such that the quantum state of each particle cannot be described independently – instead, a quantum state may be given for the system as a whole. [4]

I think that we have a simple bridge between the classical and quantum mechanics by understanding the Heisenberg Uncertainty Relations. It makes clear that the particles are not point like but have a dx and dp uncertainty.

Charting a course toward quantum simulations of nuclear physics

In nuclear physics, like much of science, detailed theories alone aren't always enough to unlock solid predictions. There are often too many pieces, interacting in complex ways, for researchers to follow the logic of a theory through to its end. It's one reason there are still so many mysteries in nature, including how the universe's basic building blocks coalesce and form stars and galaxies. The same is true in high-energy experiments, in which particles like protons smash together at incredible speeds to create extreme conditions similar to those just after the Big Bang.

Fortunately, scientists can often wield simulations to cut through the intricacies. A simulation represents the important aspects of one system—such as a plane, a town's traffic flow or an atom—as part of another, more accessible system (like a computer program or a scale model). Researchers have used their creativity to make simulations cheaper, quicker or easier to work with than the formidable subjects they investigate—like proton collisions or black holes.

Simulations go beyond a matter of convenience; they are essential for tackling cases that are both too difficult to directly observe in experiments and too complex for scientists to tease out every logical conclusion from basic principles. Diverse research breakthroughs—from modeling the complex interactions of the molecules behind life to predicting the experimental signatures that ultimately allowed the identification of the Higgs boson—have resulted from the ingenious use of simulations.

But conventional simulations only get you so far. In many cases, a simulation requires so many computations that the best computers ever built can't make meaningful progress—not even if you are willing to wait your entire life.

Now, quantum simulators (which exploit quantum effects like superposition and entanglement) promise to bring their power to bear on many problems that have refused to yield to simulations built atop classical computers—including problems in nuclear physics. But to run any simulation, quantum or otherwise, scientists must first determine how to faithfully represent their system of interest in their simulator. They must create a map between the two.

Computational nuclear physicist Zohreh Davoudi, an assistant professor of physics at the University of Maryland (UMD), is collaborating with researchers at JQI to explore how quantum simulations might aid nuclear physicists. They are working to create some of the first maps between the theories that describe the underpinnings of nuclear physics and the early quantum simulators and quantum computers being put together in labs.

"It seems like we are at the verge of going into the next phase of computing that takes advantage of quantum mechanics," says Davoudi. "And if nuclear scientists don't get into this field now—if we don't start to move our problems into such quantum hardware, we might not be able to catch up later because quantum computing is evolving very fast."

Davoudi and several colleagues, including JQI Fellows Chris Monroe and Mohammad Hafezi, designed their approach to making maps with an eye toward compatibility with the quantum technologies on the horizon. In a new paper published April 8, 2020 in the journal Physical Review Research, they describe their new method and how it creates new simulation opportunities for researchers to explore.

"It is not yet clear exactly where quantum computers will be usefully applied," says Monroe, who is also a professor of physics at UMD and co-founder of the quantum computing startup IonQ. "One strategy is to deploy them on problems that are based in quantum physics. There are many approaches in electronic structure and nuclear physics that are so taxing to normal computers that quantum computers may be a way forward."

Patterns and Control

As a first target, the team set their sights on lattice gauge theories. Gauge theories describe a wide variety of physics, including the intricate dance of quarks and gluons—the fundamental particles in nuclear physics. Lattice versions of gauge theories simplify calculations by restricting all the particles and their interactions to an orderly grid, like pieces on a chessboard.

Even with this simplification, modern computers can still choke when simulating dense clumps of matter or when tracking how matter changes over time. The team believes that quantum computers might overcome these limitations and eventually simulate more challenging types of gauge theories—such as quantum chromodynamics, which describes the strong interactions that bind quarks and gluons into protons and neutrons and hold them together as atomic nuclei.

Davoudi and her colleagues chose trapped atomic ions—the specialty of Monroe—as the physical system for performing their simulation. In these systems, ions, which are electrically charged atoms, hover, each trapped by a surrounding electric or magnetic field. Scientists can design these fields to arrange the ions in various patterns that can be used to store and transfer information. For this proposal, the team focused on ions organized into a straight line.

Researchers use lasers to control each ion and its interactions with neighbors—an essential ability when creating a useful simulation. The ions are much more accessible than the smaller particles that intrigue Davoudi. Nuclear physicists can only dream of achieving the same level of control over the interactions at the hearts of atoms.

"Take a problem at the femtometer scale and expand it to micron scale—that dramatically increases our level of control," says Hafezi, who is also an associate professor in the Department of Electrical and Computer Engineering and the Department of Physics at UMD. "Imagine you were supposed to dissect an ant. Now the ant is stretched to the distance between Boston and Los Angeles."

While designing their map-making method, the team looked at what can be done with off-the-shelf lasers. They realized that current technology allows ion trappers to set up lasers in a new, efficient way that allows for simultaneous control of three different spin interactions for each ion.

"Trapped-ion systems come with a toolbox to simulate these problems," says Hafezi. "Their amazing feature is that sometimes you can go back and design more tools and add it to the box."

With this opportunity in mind, the researchers developed a procedure for producing maps with two desirable features. First, the maps maximize how faithfully the ion-trap simulation matches a desired lattice gauge theory. Second, they minimize the errors that occur during the simulation.

In the paper, the researchers describe how this approach might allow a one-dimensional string of ions to simulate a few simple lattice gauge theories, not only in one dimension but also higher dimensions. With this approach, the behavior of ion spins can be tailored and mapped to a variety of phenomena that can be described by lattice gauge theories, such as the generation of matter and antimatter out of a vacuum.

"As a nuclear theorist, I am excited to work further with theorists and experimentalists with expertise in atomic, molecular, and optical physics and in ion-trap technology to solve more complex problems," says Davoudi. "I explained the uniqueness of my problem and my system, and they explained the features and capabilities of their system, then we brainstormed ideas on how we can do this mapping."

Monroe points out that "this is exactly what is needed for the future of quantum computing. This 'co-design' of devices tailored for specific applications is what makes the field fresh and exciting."

Analog vs. Digital

The simulations proposed by Davoudi and her colleagues are examples of analog simulations, since they directly represent elements and interactions in one system with those of another system. Generally, analog simulators must be designed for a particular problem or set of problems. This makes them less versatile than digital simulators, which have an established set of discrete building blocks that can be put together to simulate nearly anything given enough time and resources.

The versatility of digital simulations has been world-altering, but a well-designed analog system is often less complex than its digital counterpart. Carefully designed quantum analog simulations might deliver results for certain problems before quantum computers can reliably perform digital simulations. This is similar to just using a wind tunnel instead of programming a computer to model the way the wind buffets everything from a goose to an experimental fighter plane.

Monroe's team, in collaboration with coauthor Guido Pagano, a former JQI postdoctoral researcher who is now an assistant professor at Rice University, is working to implement the new analog approach within the next couple of years. The completed system should be able to simulate a variety of lattice gauge theories.

The authors say that this research is only the beginning of a longer road. Since lattice gauge theories are described in mathematically similar ways to other quantum systems, the researchers are optimistic that their proposal will find uses beyond nuclear physics, such as in condensed matter physics and materials science. Davoudi is also working to develop digital quantum simulation proposals with Monroe and Norbert Linke, another JQI Fellow. She hopes that the two projects will reveal the advantages and disadvantages of each approach and provide insight into how researchers can tackle nuclear physics problems with the full might of quantum computing.

"We want to eventually simulate theories of a more complex nature and in particular quantum chromodynamics that is responsible for the strong force in nature," says Davoudi. "But that might require thinking even more outside the box." [19]

Quantum simulation more stable than expected

A localization phenomenon boosts the accuracy of solving quantum many-body problems with quantum computers. These problems are otherwise challenging for conventional computers. This brings such digital quantum simulation within reach using quantum devices available today.

Quantum computers promise to solve certain computational problems exponentially faster than any classical machine. "A particularly promising application is the solution of quantum many-body problems utilizing the concept of digital quantum simulation," says Markus Heyl from Max Planck Institute for the Physics of Complex in Dresden, Germany. "Such simulations could have a major impact on quantum chemistry, materials scienceand fundamental physics."

Within digital quantum simulation, the time evolution of the targeted quantum many-body system is realized by a sequence of elementary quantum gates by discretizing time evolution, a process called Trotterization. "A fundamental challenge, however, is the control of an intrinsic error source, which appears due to this discretization," says Markus Heyl.

Together with international colleagues, they showed in a recent *Science Advances* article that quantum localization by constraining the time evolution through quantum interference strongly bounds these errors for local observables.

More robust than expected

"Digital quantum simulation is thus intrinsically much more robust than what one might expect from known error bounds on the global many-body wave function," Heyl says. This robustness is characterized by a sharp threshold as a function of the utilized time granularity measured by the so-called Trotter step size. The threshold separates a regular region with controllable Trotter errors, where the system exhibits localization in the space of eigenstates of the time-evolution operator, from a quantum chaotic regime where errors accumulate quickly rendering the outcome of the quantum simulation unusable.

"Our findings show that digital quantum simulation with comparatively large Trotter steps can retain controlled Trotter errors for local observables," says Markus Heyl. "It is thus possible to reduce the number of quantum gate operations required to represent the desired time evolution faithfully, thereby mitigating the effects of imperfect individual gate operations." This brings digital quantum simulation for classically challenging quantum many-body problems within reach for current day quantum devices. [18]

Research provides speed boost to quantum computers

A new finding by researchers at the University of Chicago promises to improve the speed and reliability of current and next generation quantum computers by as much as ten times. By combining principles from physics and computer science, the researchers developed a new scalable compiler that makes software aware of the underlying quantum hardware, offering significant performance benefits as scientists race to build the first practical quantum computers.

The UChicago research group comprises computer scientists and physicists from the EPiQC (Enabling Practical-scale Quantum Computation) collaboration, an NSF Expedition in Computing that kicked off in 2018. EPiQC aims to bridge the gap from existing theoretical algorithms to practical quantum computing architectures on near-term devices.

Merging Approaches from Computer Science and Physics

The core technique behind the EPiQC team's paper adapts quantum optimal control, an approach developed by physicists long before quantum computing was possible. Quantum optimal control fine-tunes the control knobs of quantum systems in order to continuously drive particles to desired quantum states—or in a computing context, implement a desired program.

If successfully adapted, quantum optimal control would allow quantum computers to execute programs at the highest possible efficiency...but that comes with a performance tradeoff.

A short video describing the work. Credit: University of Chicago

"Physicists have actually been using quantum optimal control to manipulate small systems for many years, but the issue is that their approach doesn't scale," said researcher Yunong Shi.

Even with cutting-edge hardware, it takes several hours to run quantum optimal control targeted to a machine with just 10 quantum bits (qubits). Moreover, this running time scales exponentially, which makes quantum optimal control untenable for the 20-100 qubit machines expected in the coming year.

Meanwhile, computer scientists have developed their own methods for compiling quantum programs down to the control knobs of quantum hardware. The computer science approach has the advantage of scalability—compilers can easily compile programs for machines with thousands of qubits. However, these compilers are largely unaware of the underlying quantum hardware. Often, there is a severe mismatch between the quantum operations that the software deals with versus the ones that the hardware executes. As a result, the compiled programs are inefficient.

The EPiQC team's work merges the computer science and physics approaches by intelligently splitting large quantum programs into subprograms. Each subprogram is small enough that it can be handled by the physics approach of quantum optimal control, without running into performance issues. This approach realizes both the program-level scalability of traditional compilers from the computer science world and the subprogram-level efficiency gains of quantum optimal control.

The intelligent generation of subprograms is driven by an algorithm for exploiting commutativity—a phenomenon in which quantum operations can be rearranged in any order. Across a wide range of quantum algorithms, relevant both in the near-term and long-term, the EPiQC team's compiler achieves two to ten times execution speedups over the baseline. But due to the fragility of qubits, the speedups in quantum program execution translate to exponentially higher success rates for the ultimate computation. As Shi emphasizes, "on quantum computers, speeding up your execution time is do-or-die."

Breaking Abstraction Barriers

This new compiler technique is a significant departure from previous work. "Past compilers for quantum programs have been modeled after compilers for modern conventional computers," said Fred Chong, Seymour Goodman Professor of Computer Science at UChicago and lead PI for EPiQC. But unlike conventional computers, quantum computers are notoriously fragile and noisy, so techniques optimized for conventional computers don't port well to quantum computers. "Our new compiler is unlike the previous set of classically-inspired compilers because it breaks the abstraction barrier between quantum algorithms and quantum hardware, which leads to greater efficiency at the cost of having a more complex compiler."

While the team's research revolves around making the compiler software aware of the underlying hardware, it is agnostic to the specific type of underlying hardware. This is important since there are several different types of quantum computers currently under development, such as ones with superconducting qubits and trapped ion qubits.

The team expects to see experimental realizations of their approach within the coming months, particularly now that an open industry standard, OpenPulse, has been defined. This standard will enable operation of quantum computers at the lowest possible level, as needed for quantum optimal control techniques. IBM's quantum roadmap highlights OpenPulse support as a key objective for 2019, and other companies are expected to announce similar plans as well.

The team's full paper, "Optimized Compilation of Aggregated Instructions for Realistic Quantum Computers" is now published on arXiv and will be presented at the ASPLOS computer architecture conference in Rhode Island on April 17. In addition to Shi and Chong, co-authors include Nelson Leung, Pranav Gokhale, Zane Rossi, David I. Schuster, and Henry Hoffman, all at the University of Chicago. [17]

New algorithm optimizes quantum computing problem-solving

Tohoku University researchers have developed an algorithm that enhances the ability of a Canadian-designed quantum computer to more efficiently find the best solution for complicated problems, according to a study published in the journal *Scientific Reports*.

Quantum computing takes advantage of the ability of subatomic particles to exist in more than one state at the same time. It is expected to take modern-day computing to the next level by enabling the processing of more information in less time.

The D-Wave quantum annealer, developed by a Canadian company that claims it sells the world's first commercially available quantum computers, employs the concepts of quantum physics to solve 'combinatorial optimization problems.' A typical example of this sort of problem asks the question: "Given a list of cities and the distances between each pair of cities, what is the shortest possible route that visits each city and returns to the original city?" Businesses and industries face a large range of similarly complex problems in which they want to find the optimal solution among many possible ones using the least amount of resources.

Ph. D candidate Shuntaro Okada and information scientist Masayuki Ohzeki of Japan's Tohoku University collaborated with global automotive components manufacturer Denso Corporation and other colleagues to develop an algorithm that improves the D-Wave quantum annealer's ability to solve combinatorial optimization problems.

The algorithm works by partitioning an originally large problem into a group of subproblems. The D-Wave annealer then iteratively optimizes each subproblem to eventually solve the original larger one. The Tohoku University algorithm improves on another algorithm using the same concept by allowing the use of larger subproblems, ultimately leading to the arrival at more optimal solutions more efficiently.

"The proposed algorithm is also applicable to the future version of the D-Wave quantum annealer, which contains many more qubits," says Ohzeki. Qubits, or quantum bits, form the basic unit in quantum computing. "As the number of qubits mounted in the D-Wave quantum annealer increases, we will be able to obtain even better solutions," he says.

The team next aims to assess the utility of their algorithm for various optimization problems. [16]

D-Wave demonstrates first large-scale quantum simulation of topological state of matter

D-Wave Systems today published a milestone study demonstrating a topological phase transition using its 2048-qubit annealing quantum computer. This complex quantum simulation of materials is a major step toward reducing the need for time-consuming and expensive physical research and development.

The paper, entitled "Observation of topological phenomena in a programmable lattice of 1,800 qubits", was published in the peer-reviewed journal *Nature*. This work marks an important advancement in the field and demonstrates again that the fully programmable D-Wave quantum computer can be used as an accurate simulator of quantum systems at a large scale. The methods used in this work could have broad implications in the development of novel materials, realizing Richard Feynman's original vision of a quantum simulator. This new research comes on the heels of D-Wave's recent *Science*paper demonstrating a different type of phase transition in a quantum spin-glass simulation. The two papers together signify the flexibility and versatility of the D-Wave quantum computer in quantum simulation of materials, in addition to other tasks such as optimization and machine learning.

In the early 1970s, theoretical physicists Vadim Berezinskii, J. Michael Kosterlitz and David Thouless predicted a new state of matter characterized by nontrivial topological properties. The work was awarded the Nobel Prize in Physics in 2016. D-Wave researchers demonstrated this phenomenon by programming the D-Wave 2000Q system to form a two-dimensional frustrated lattice of artificial spins. The observed topological properties in the simulated system cannot exist without quantum effects and closely agree with theoretical predictions.

"This paper represents a breakthrough in the simulation of physical systems which are otherwise essentially impossible," said 2016 Nobel laureate Dr. J. Michael Kosterlitz. "The test reproduces most of the expected results, which is a remarkable achievement. This gives hope that future quantum simulators will be able to explore more complex and poorly understood systems so that one can trust the simulation results in quantitative detail as a model of a physical system. I look forward to seeing future applications of this simulation method."

"The work described in the *Nature* paper represents a landmark in the field of quantum computation: for the first time, a theoretically predicted state of matter was realized in quantum simulation before being demonstrated in a real magnetic material," said Dr. Mohammad Amin, chief scientist at D-Wave. "This is a significant step toward reaching the goal of quantum simulation, enabling the study of material properties before making them in the lab, a process that today can be very costly and time consuming." [15]

Scientists make leap in simulating quantum particles

New quantum theory research, led by academics at the University of St Andrews' School of Physics, could transform the way scientists predict how quantum particles behave.

Quantum theory is a cornerstone of modern physics, explaining the behaviour of isolated particles, like the electrons that orbit atoms. It has shown us that quantum particles have great potential for applications, such as powerful quantum computers with the potential to solve complex problems much more quickly than conventional computers.

In recent years, the possibility of using the states of quantum particles to hold information has become a reality in the laboratory. This has led to the development of quantum processors made of just a few quantum bits, 'qubits' - particles that store a particular quantum state. Unlike the bits in conventional computers, which can be either zero or one, a qubit can be in a 'superposition' of zero and one at the same time. If calculations can be done on this superposition, it allows some problems, like searching databases to be done faster than on regular computers.

The new research, published in *Nature Communications* (Monday 20 August), which focussed on the behaviours of individual qubits, opens the possibility of more faithful simulations of the next generation of quantum processors and could allow new insights into quantum mechanics and the development of powerful quantum computers.

The study, led by theoretical physicists, Dr. Brendon Lovett and Dr. Jonathan Keeling, noted that if real qubits behaved like the textbook qubits, the quest to build a quantum computer would be easy. However, unlike the textbook models of qubits, real-life qubits are never truly isolated, they interact continuously with the vast number of other particles in the world. This means that trying to create a mathematical model of a qubit's behaviour is very difficult, since we now also need to keep track of what the rest of the world is doing as well. To do this explicitly requires an amount of information that cannot be stored, even on the biggest computers we have. To avoid this, simple models of the interaction between individual qubits and the rest of the world are often used, but these can miss crucial effects.

Dr. Lovett said: "Our research has found a ground-breaking new way of keeping the most relevant fraction of information, allowing an exact description of the behaviour of the qubit even on a regular laptop. This work not only opens up the possibility of more faithful simulations of the next generation of quantum processors but could allow us whole new insights into how quantum mechanics works when many particles are put together."

The paper 'Efficient non-Markovian quantum dynamics using time-evolving matrix product operators' is published in *Nature Communications*. [14]

Intel unveils 49-qubit superconducting chip

Intel has announced the design and fabrication of a 49-qubit superconducting quantum-processor chip at the Consumer Electronics Show in Las Vegas. Speaking at the conference, Intel chief executive Brian Krzanich introduced “Tangle Lake”; a quantum-processor chip that operates at extremely low temperatures. The device takes its name from the Tangle Lakes, a frigid chain of lakes in Alaska, and is a nod to quantum entanglement.

Tangle Lake is designed to store and process quantum information in qubits that are superconducting circuits. Krzanich said that the chip is an important step towards developing quantum computers that could quickly solve mathematical problems involved in some of society's most pressing issues – from drug development to climate forecasting.

Large-scale integration

He also announced progress in Intel's research on spin qubits, which have qubits based on the spin states of single electrons. While superconducting chips tend to be relatively large, the spin-qubits could be miniaturized using well-established silicon-chip fabrication processes. This means that it may be possible to manufacture quantum processors containing large numbers of spin qubits. This large-scale integration would be could be more difficult for superconducting qubits.

However, there is some scepticism in the physics community regarding Intel's silence about the performance and quality specifications of Tangle Lake and their spin qubit chips. Intel is also facing fierce competition. IBM has itself announced quantum computers with 20 and 50 superconducting qubits in recent months, and companies including Google and Rigetti are also securing footholds in the nascent market.

Commercial quest

"In the quest to deliver a commercially viable quantum computing system, it's anyone's game," confesses Mike Mayberry, managing director at Intel Labs. "We expect it will be five to seven years before the industry gets to tackling engineering-scale problems, and it will likely require one million or more qubits to achieve commercial relevance." [13]

Scientists explore quantum properties in the two-dimensional limit

As electronic components become smaller, understanding how materials behave at the nanoscale is crucial for the development of next-generation electronics. Unfortunately, it is very difficult to predict what happens when materials are only a few atomic layers thick. To improve our understanding of the so-called quantum properties of materials, scientists at the TU Delft investigated thin slices of $SrIrO_3$, a material that belongs to the family of complex oxides. Their findings have recently been published *Physical Review Letters*.

The researchers synthesized the material using pulsed laser deposition (PLD), a method for depositing single crystal films with atomic layer precision. "We studied crystals with thicknesses down to 2 atomic layers (0.8 nanometres)," said lead author Dirk Groenendijk, who is a Ph.D. candidate at TU Delft.

Electrons can normally move freely in the material, and $SrIrO_3$ shows metallic behaviour. However, the scientists found that at a thickness of 4 layers, there appears to be a turning point. Below this thickness, the electrons become localized and the material transitions to an insulating state. At the same time, the material orders magnetically and the effects of spin-orbit coupling are strongly enhanced. This last property is of interest for the development of new magnetic memory devices, because the spin of the electron can be used to store and transfer information.

The next generation of electronic devices will require further miniaturization of their components, and it will not be long before chip manufacturers go below 10 nanometres. "At this scale, you can count the number of atoms, and you enter the realm of quantum mechanics," says Groenendijk. For future devices, researchers are also looking for new materials with currently inaccessible functionalities. In this respect, complex oxides are promising candidates that display a wide variety of exotic phenomena. The research of Groenendijk and colleagues constitutes an important step towards the understanding of their quantum properties in the two-dimensional limit. [12]

Do Physicists Need to Change the Way They Measure Quantum States?

New research carried out by CQT researchers suggest that standard protocols that measure the dimensions of quantum systems may return incorrect numbers. For that reason, Cai Yu, Cong Wan and Valerio Scarani and Jean Bancal want to create a new concept of 'irreducible dimensions.' However, in doing so, physicists will need to re-evaluate how they'll measure the dimensions of quantum states moving forward.

The CQT researchers concentrate on Hilbert Space when conducting their research, which is a realm of potentially infinite dimensions that are inhabited by quantum systems. "The goal of our paper is to show there is a conceptual problem in how dimension witnesses are defined," confirms Valerio Scarani, CQT Principal Investigator.

For proper implementation of quantum communication and protocols, accurate measuring is needed, and that's where the Hilbert Space dimension comes in. This part of the quantum system will let you know exactly how much information can be stored in the system.

In completing their research, the team discovered that the measurement protocols designed to calculate the dimension of a state (the dimension witness) were unable to distinguish between a high-dimension state and a low one. One of the first to raise doubts about the way in which dimension witnesses worked was Post doctorate Jean-Daniel.

Valerio told everyone to stop and reset, and the team proceeded to rewrite their conclusions. While some of the team were doing this, Wan and Cai began working on a new theory involving dimension witnesses, leading to the publishing of their paper. [11]

Entanglement is an inevitable feature of reality

Is entanglement really necessary for describing the physical world, or is it possible to have some post-quantum theory without entanglement?

In a new study, physicists have mathematically proved that any theory that has a classical limit—meaning that it can describe our observations of the classical world by recovering classical theory under certain conditions—must contain entanglement. So despite the fact that entanglement goes against classical intuition, entanglement must be an inevitable feature of not only quantum theory but also any non-classical theory, even those that are yet to be developed.

The physicists, Jonathan G. Richens at Imperial College London and University College London, John

H. Selby at Imperial College London and the University of Oxford, and Sabri W. Al-Safi at Nottingham Trent University, have published a paper establishing entanglement as a necessary feature of any non-classical theory in a recent issue of Physical Review Letters.

"Quantum theory has many strange features compared to classical theory," Richens told Phys.org. "Traditionally we study how the classical world emerges from the quantum, but we set out to reverse this reasoning to see how the classical world shapes the quantum. In doing so we show that one of its strangest features, entanglement, is totally unsurprising. This hints that much of the apparent strangeness of quantum theory is an inevitable consequence of going beyond classical theory, or perhaps even a consequence of our inability to leave classical theory behind."

Although the full proof is very detailed, the main idea behind it is simply that any theory that describes reality must behave like classical theory in some limit. This requirement seems pretty obvious, but as the physicists show, it imparts strong constraints on the structure of any nonclassical theory.

Quantum theory fulfills this requirement of having a classical limit through the process of decoherence. When a quantum system interacts with the outside environment, the system loses its quantum coherence and everything that makes it quantum. So the system becomes classical and behaves as expected by classical theory.

Here, the physicists show that any non-classical theory that recovers classical theory must contain entangled states. To prove this, they assume the opposite: that such a theory does not have entanglement. Then they show that, without entanglement, any theory that recovers classical theory must be classical theory itself—a contradiction of the original hypothesis that the theory in question is non-classical. This result implies that the assumption that such a theory does not have entanglement is false, which means that any theory of this kind must have entanglement.

This result may be just the beginning of many other related discoveries, since it opens up the possibility that other physical features of quantum theory can be reproduced simply by requiring that the theory has a classical limit. The physicists anticipate that features such as information causality, bit symmetry, and macroscopic locality may all be shown to arise from this single requirement. The results also provide a clearer idea of what any future non-classical, post-quantum theory must look like.

"My future goals would be to see if Bell non-locality can likewise be derived from the existence of a classical limit," Richens said. "It would be interesting if all theories superseding classical theory must violate local realism. I am also working to see if certain extensions of quantum theory (such as higher order interference) can be ruled out by the existence of a classical limit, or if this limit imparts useful constraints on these 'post-quantum theories.'" [10]

Bell Prize goes to scientists who proved 'spooky' quantum entanglement is real

A trio of scientists who defied Einstein by proving the nonlocal nature of quantum entanglement will be honoured with the John Stewart Bell Prize from the University of Toronto (U of T). The prize recognizes the most significant recent achievements in the world in quantum mechanics and is considered by many to be the top international award in the field.

The recipients each led separate experiments in 2015 that showed two particles so distant from one another that no signal could connect them even at the speed of light nevertheless possessed an invisible and instantaneous connection. They are:

Ronald Hanson, Delft University of Technology, Netherlands

Sae-Woo Nam of the National Institute of Standards & Technology, United States

Anton Zeilinger, University of Vienna, Austria

According to quantum entanglement, the world is a very weird place where quantum particles become correlated in pairs. These pairs predictably interact with each other regardless of how far apart they are: if you measure the properties of one member of the entangled pair you know the properties of the other. Einstein was not a believer: in the 1930s, he called it "spooky action at a distance."

"While many experiments have come close to proving quantum entanglement, the scientists we are honouring have closed previous loopholes," says Professor Aephraim Steinberg, a quantum physicist at the U of T's Centre for Quantum Information & Quantum Control (CQIQC) and one of the founders of the Bell Prize. Earlier tests, for example, were plagued by the difficulties of ensuring that no signal could make it from one detector to the other as well as the fact that so many photons were being lost in the test process.

"Collectively, they have removed all reasonable doubt about the nonlocal nature of quantum entanglement. In so doing they are also opening the door to exciting new technologies including super-secure communications and the ability to perform certain computations exponentially faster than any classical computer," says Steinberg.

Created by the CQIQC at U of T in 2005, the John Stewart Bell Prize for Research on Fundamental Issues in Quantum Mechanics and their Applications is judged by an international panel of experts and awarded every two years for achievements in the previous six years.

"Advancing understanding of quantum mechanics, along with its technological applications, is something that deserves to be celebrated and recognized around the world. We expect that, in some cases, the Bell Prize will prove to be a precursor to the Nobel Prize in Physics," says Daniel James, director of the CQIQC.

The prize will be awarded on Thursday, August 31 at 1:25 pm at the Fields Institute on the U of T campus. Recipients will give short talks after the ceremony. [9]

How to Win at Bridge Using Quantum Physics

Contract bridge is the chess of card games. You might know it as some stuffy old game your grandparents play, but it requires major brainpower, and preferably an obsession with rules and strategy. So how to make it even geekier? Throw in some quantum mechanics to try to gain a competitive advantage. The idea here is to use the quantum magic of entangled photons–which are essentially twins, sharing every property–to transmit two bits of information to your bridge partner for the price of one. Understanding how to do this is not an easy task, but it will help elucidate some basic building blocks of quantum information theory. It's also kind of fun to consider whether or not such tactics could ever be allowed in professional sports. [6]

Quantum Information

In quantum mechanics, quantum information is physical information that is held in the "state" of a quantum system. The most popular unit of quantum information is the qubit, a two-level quantum system. However, unlike classical digital states (which are discrete), a two-state quantum system can actually be in a superposition of the two states at any given time.

Quantum information differs from classical information in several respects, among which we note the following:

However, despite this, the amount of information that can be retrieved in a single qubit is equal to one bit. It is in the processing of information (quantum computation) that a difference occurs.

The ability to manipulate quantum information enables us to perform tasks that would be unachievable in a classical context, such as unconditionally secure transmission of information. Quantum information processing is the most general field that is concerned with quantum information. There are certain tasks which classical computers cannot perform "efficiently" (that is, in polynomial time) according to any known algorithm. However, a quantum computer can compute the answer to some of these problems in polynomial time; one well-known example of this is Shor's factoring algorithm. Other algorithms can speed up a task less dramatically - for example, Grover's search algorithm which gives a quadratic speed-up over the best possible classical algorithm.

Quantum information, and changes in quantum information, can be quantitatively measured by using an analogue of Shannon entropy. Given a statistical ensemble of quantum mechanical systems with the density matrix S, it is given by.

Many of the same entropy measures in classical information theory can also be generalized to the quantum case, such as the conditional quantum entropy. [7]

Quantum Teleportation

Quantum teleportation is a process by which quantum information (e.g. the exact state of an atom or photon) can be transmitted (exactly, in principle) from one location to another, with the help of classical communication and previously shared quantum entanglement between the sending and receiving location. Because it depends on classical communication, which can proceed no faster than the speed of light, it cannot be used for superluminal transport or communication of classical bits. It also cannot be used to make copies of a system, as this violates the no-cloning theorem. Although the name is inspired by the teleportation commonly used in fiction, current technology provides no possibility of anything resembling the fictional form of teleportation. While it is possible to teleport one or more qubits of information between two (entangled) atoms, this has not yet been achieved between molecules or anything larger. One may think of teleportation either as a kind of transportation, or as a kind of communication; it provides a way of transporting a qubit from one location to another, without having to move a physical particle along with it.

The seminal paper first expounding the idea was published by C. H. Bennett, G. Brassard, C. Crépeau, R. Jozsa, A. Peres and W. K. Wootters in 1993. Since then, quantum teleportation has been realized in various physical systems. Presently, the record distance for quantum teleportation is 143 km (89 mi) with photons, and 21 m with material systems. In August 2013, the achievement of "fully deterministic" quantum teleportation, using a hybrid technique, was reported. On 29 May 2014, scientists announced a reliable way of transferring data by quantum teleportation. Quantum teleportation of data had been done before but with highly unreliable methods. [8]

Quantum Computing

A team of electrical engineers at UNSW Australia has observed the unique quantum behavior of a pair of spins in silicon and designed a new method to use them for "2-bit" quantum logic operations.

These milestones bring researchers a step closer to building a quantum computer, which promises dramatic data processing improvements.

Quantum bits, or qubits, are the building blocks of quantum computers. While many ways to create a qubits exist, the Australian team has focused on the use of single atoms of phosphorus, embedded inside a silicon chip similar to those used in normal computers.

The first author on the experimental work, PhD student Juan Pablo Dehollain, recalls the first time he realized what he was looking at.

"We clearly saw these two distinct quantum states, but they behaved very differently from what we were used to with a single atom. We had a real 'Eureka!' moment when we realized what was happening – we were seeing in real time the `entangled' quantum states of a pair of atoms." [5]

Quantum Entanglement

Measurements of physical properties such as position, momentum, spin, polarization, etc. performed on entangled particles are found to be appropriately correlated. For example, if a pair of particles is generated in such a way that their total spin is known to be zero, and one particle is found to have clockwise spin on a certain axis, then the spin of the other particle, measured on the same axis, will be found to be counterclockwise. Because of the nature of quantum measurement, however, this behavior gives rise to effects that can appear paradoxical: any measurement of a property of a particle can be seen as acting on that particle (e.g. by collapsing a number of superimposed states); and in the case of entangled particles, such action must be on the entangled system as a whole. It thus appears that one particle of an entangled pair "knows" what measurement has been performed on the other, and with what outcome, even though there is no known means for such information to be communicated between the particles, which at the time of measurement may be separated by arbitrarily large distances. [4]

The Bridge

The accelerating electrons explain not only the Maxwell Equations and the Special Relativity, but the Heisenberg Uncertainty Relation, the wave particle duality and the electron's spin also, building the bridge between the Classical and Quantum Theories. [1]

Accelerating charges

The moving charges are self maintain the electromagnetic field locally, causing their movement and this is the result of their acceleration under the force of this field. In the classical physics the charges will distributed along the electric current so that the electric potential lowering along the current, by linearly increasing the way they take every next time period because this accelerated motion. The same thing happens on the atomic scale giving a dp impulse difference and a dx way difference between the different part of the not point like particles.

Relativistic effect

Another bridge between the classical and quantum mechanics in the realm of relativity is that the charge distribution is lowering in the reference frame of the accelerating charges linearly: ds/dt = at (time coordinate), but in the reference frame of the current it is parabolic: $s = a/2\ t^2$ (geometric coordinate).

Heisenberg Uncertainty Relation

In the atomic scale the Heisenberg uncertainty relation gives the same result, since the moving electron in the atom accelerating in the electric field of the proton, causing a charge distribution on delta x position difference and with a delta p momentum difference such a way that they product is about the half Planck reduced constant. For the proton this delta x much less in the nucleon, than in the orbit of the electron in the atom, the delta p is much higher because of the greater proton mass.

This means that the electron and proton are not point like particles, but has a real charge distribution.

Wave – Particle Duality

The accelerating electrons explains the wave – particle duality of the electrons and photons, since the elementary charges are distributed on delta x position with delta p impulse and creating a wave packet of the electron. The photon gives the electromagnetic particle of the mediating force of the electrons electromagnetic field with the same distribution of wavelengths.

Atomic model

The constantly accelerating electron in the Hydrogen atom is moving on the equipotential line of the proton and it's kinetic and potential energy will be constant. Its energy will change only when it is changing its way to another equipotential line with another value of potential energy or getting free with enough kinetic energy. This means that the Rutherford-Bohr atomic model is right and only that changing acceleration of the electric charge causes radiation, not the steady acceleration. The steady acceleration of the charges only creates a centric parabolic steady electric field around the charge, the magnetic field. This gives the magnetic moment of the atoms, summing up the proton and electron magnetic moments caused by their circular motions and spins.

The Relativistic Bridge

Commonly accepted idea that the relativistic effect on the particle physics it is the fermions' spin - another unresolved problem in the classical concepts. If the electric charges can move only with accelerated motions in the self maintaining electromagnetic field, once upon a time they would reach the velocity of the electromagnetic field. The resolution of this problem is the spinning particle, constantly accelerating and not reaching the velocity of light because the acceleration is radial. One origin of the Quantum Physics is the Planck Distribution Law of the electromagnetic oscillators, giving equal intensity for 2 different wavelengths on any temperature. Any of these two wavelengths will give equal intensity diffraction patterns, building different asymmetric constructions, for example proton - electron structures (atoms), molecules, etc. Since the particles are centers of diffraction patterns they also have particle – wave duality as the electromagnetic waves have. [2]

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. The Electroweak Interaction shows that the Weak Interaction is basically electromagnetic in nature. The arrow of time shows the entropy grows by changing the temperature dependent diffraction patterns of the electromagnetic oscillators.

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 General Weak Interaction

The Weak Interactions 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 for example the Hydrogen fusion. The arrow of time by the Second Law of Thermodynamics shows the increasing entropy and decreasing information by the Weak Interaction, changing the temperature dependent diffraction patterns. A good example of this is the neutron decay, creating more particles with less known information about them.

The neutrino oscillation of the Weak Interaction shows that it is a general electric dipole change and it is possible to any other temperature dependent entropy and information changing diffraction pattern of atoms, molecules and even complicated biological living structures.

We can generalize the weak interaction on all of the decaying matter constructions, even on the biological too. This gives the limited lifetime for the biological constructions also by the arrow of time. There should be a new research space of the Quantum Information Science the 'general neutrino oscillation' for the greater then subatomic matter structures as an electric dipole change.

There is also connection between statistical physics and evolutionary biology, since the arrow of time is working in the biological evolution also.
The Fluctuation Theorem says that there is a probability that entropy will flow in a direction opposite to that dictated by the Second Law of Thermodynamics. In this case the Information is growing that is the matter formulas are emerging from the chaos. So the Weak Interaction has two directions, samples for one direction is the Neutron decay, and Hydrogen fusion is the opposite direction.

Fermions and Bosons

The fermions are the diffraction patterns of the bosons such a way that they are both sides of the same thing.

Van Der Waals force

Named after the Dutch scientist Johannes Diderik van der Waals – who first proposed it in 1873 to explain the behaviour of gases – it is a very weak force that only becomes relevant when atoms and molecules are very close together. Fluctuations in the electronic cloud of an atom mean that it will have an instantaneous dipole moment. This can induce a dipole moment in a nearby atom, the result being an attractive dipole–dipole interaction.

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]

Relativistic change of mass

The increasing mass of the electric charges the result of the increasing inductive electric force acting against the accelerating force. The decreasing mass of the decreasing acceleration is the result of the inductive electric force acting against the decreasing force. This is the relativistic mass change explanation, especially importantly explaining the mass reduction in case of velocity decrease.

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 – can be seen as a gravitational force. [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.

Gravity from the point of view of quantum physics

The Gravitational force

The gravitational attractive force is basically a magnetic force.

The same electric charges can attract one another by the magnetic force if they are moving parallel in the same direction. Since the electrically neutral matter is composed of negative and positive charges they need 2 photons to mediate this attractive force, one per charges. The Bing Bang caused parallel moving of the matter gives this magnetic force, experienced as gravitational force.

Since graviton is a tensor field, it has spin = 2, could be 2 photons with spin = 1 together.

You can think about photons as virtual electron – positron pairs, obtaining the necessary virtual mass for gravity.

The mass as seen before a result of the diffraction, for example the proton – electron mass rate Mp=1840 Me. In order to move one of these diffraction maximum (electron or proton) we need to intervene into the diffraction pattern with a force appropriate to the intensity of this diffraction maximum, means its intensity or mass.

The Big Bang caused acceleration created radial currents of the matter, and since the matter is composed of negative and positive charges, these currents are creating magnetic field and attracting forces between the parallel moving electric currents. This is the gravitational force experienced by the matter, and also the mass is result of the electromagnetic forces between the charged particles. The positive and negative charged currents attracts each other or by the magnetic forces or by the much stronger electrostatic forces!?

The gravitational force attracting the matter, causing concentration of the matter in a small space and leaving much space with low matter concentration: dark matter and energy.

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 Higgs boson

By March 2013, the particle had been proven to behave, interact and decay in many of the expected ways predicted by the Standard Model, and was also tentatively confirmed to have + parity and zero spin, two fundamental criteria of a Higgs boson, making it also the first known scalar particle to be discovered in nature, although a number of other properties were not fully proven and some partial results do not yet precisely match those expected; in some cases data is also still awaited or being analyzed.

Since the Higgs boson is necessary to the W and Z bosons, the dipole change of the Weak interaction and the change in the magnetic effect caused gravitation must be conducted. The Wien law is also important to explain the Weak interaction, since it describes the T_{max} change and the diffraction patterns change. [2]

Higgs mechanism and Quantum Gravity

The magnetic induction creates a negative electric field, causing an electromagnetic inertia. Probably it is the mysterious Higgs field giving mass to the charged particles? We can think about the photon as an electron-positron pair, they have mass. The neutral particles are built from negative and positive charges, for example the neutron, decaying to proton and electron. The wave – particle duality makes sure that the particles are oscillating and creating magnetic induction as an inertial mass, explaining also the relativistic mass change. Higher frequency creates stronger magnetic induction, smaller frequency results lesser magnetic induction. It seems to me that the magnetic induction is the secret of the Higgs field.

In particle physics, the Higgs mechanism is a kind of mass generation mechanism, a process that gives mass to elementary particles. According to this theory, particles gain mass by interacting with the Higgs field that permeates all space. More precisely, the Higgs mechanism endows gauge bosons in a gauge theory with mass through absorption of Nambu–Goldstone bosons arising in spontaneous symmetry breaking.

The simplest implementation of the mechanism adds an extra Higgs field to the gauge theory. The spontaneous symmetry breaking of the underlying local symmetry triggers conversion of components of this Higgs field to Goldstone bosons which interact with (at least some of) the other fields in the theory, so as to produce mass terms for (at least some of) the gauge bosons. This mechanism may also leave behind elementary scalar (spin-0) particles, known as Higgs bosons.

In the Standard Model, the phrase "Higgs mechanism" refers specifically to the generation of masses for the $W^{\pm}$, and Z weak gauge bosons through electroweak symmetry breaking. The Large Hadron Collider at CERN announced results consistent with the Higgs particle on July 4, 2012 but stressed that further testing is needed to confirm the Standard Model.

What is the Spin?

So we know already that the new particle has spin zero or spin two and we could tell which one if we could detect the polarizations of the photons produced. Unfortunately this is difficult and neither ATLAS nor CMS are able to measure polarizations. The only direct and sure way to confirm that the particle is indeed a scalar is to plot the angular distribution of the photons in the rest frame of the centre of mass. A spin zero particles like the Higgs carries no directional information away from the original collision so the distribution will be even in all directions. This test will be possible when a much larger number of events have been observed. In the mean time we can settle for less certain indirect indicators.

The Graviton

In physics, the graviton is a hypothetical elementary particle that mediates the force of gravitation in the framework of quantum field theory. If it exists, the graviton is expected to be massless (because the gravitational force appears to have unlimited range) and must be a spin-2 boson. The spin follows from the fact that the source of gravitation is the stress-energy tensor, a second-rank tensor (compared to electromagnetism's spin-1 photon, the source of which is the four-current, a first-rank tensor). Additionally, it can be shown that any massless spin-2 field would give rise to a force indistinguishable from gravitation, because a massless spin-2 field must couple to (interact with) the stress-energy tensor in the same way that the gravitational field does. This result suggests that, if a massless spin-2 particle is discovered, it must be the graviton, so that the only experimental verification needed for the graviton may simply be the discovery of a massless spin-2 particle. [3]

Conclusions

In August 2013, the achievement of "fully deterministic" quantum teleportation, using a hybrid technique, was reported. On 29 May 2014, scientists announced a reliable way of transferring data by quantum teleportation. Quantum teleportation of data had been done before but with highly unreliable methods. [8]

One of the most important conclusions is that the electric charges are moving in an accelerated way and even if their velocity is constant, they have an intrinsic acceleration anyway, the so called spin, since they need at least an intrinsic acceleration to make possible they movement .

The accelerated charges self-maintaining potential shows the locality of the relativity, working on the quantum level also. [1]

The bridge between the classical and quantum theory is based on this intrinsic acceleration of the spin, explaining also the Heisenberg Uncertainty Principle. The particle – wave duality of the electric charges and the photon makes certain that they are both sides of the same thing. The Secret of Quantum Entanglement that the particles are diffraction patterns of the electromagnetic waves and this way their quantum states every time is the result of the quantum state of the intermediate electromagnetic waves. [2]

The key breakthrough to arrive at this new idea to build qubits was to exploit the ability to control the nuclear spin of each atom. With that insight, the team has now conceived a unique way to use the nuclei as facilitators for the quantum logic operation between the electrons. [5]
Basing the gravitational force on the accelerating Universe caused magnetic force and the Planck Distribution Law of the electromagnetic waves caused diffraction gives us the basis to build a Unified Theory of the physical interactions also.

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