Quantum Gas don't Take the Heat

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Building on his own previous research, Amherst College professor David S. Hall '91 and a team of international collaborators have experimentally identified a pointlike monopole in a quantum field for the first time. The discovery, announced this week, gives scientists further insight into the elusive monopole magnet, an elementary particle that researchers believe exists but have not yet seen in nature. [11]

For the first time, physicists have achieved interference between two separate atoms: when sent towards the opposite sides of a semi-transparent mirror, the two atoms always emerge together. This type of experiment, which was carried out with photons around thirty years ago, had so far been impossible to perform with matter, due to the extreme difficulty of creating and manipulating pairs of indistinguishable atoms. [10]

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.

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.

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Preface

Physicists are continually looking for ways to unify the theory of relativity, which describes largescale phenomena, with quantum theory, which describes small-scale phenomena. In a new proposed experiment in this area, two toaster-sized "nanosatellites" carrying entangled condensates orbit around the Earth, until one of them moves to a different orbit with different gravitational field strength. As a result of the change in gravity, the entanglement between the condensates is predicted to degrade by up to 20%. Experimentally testing the proposal may be possible in the near future. [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.

Quantum gases won't take the heat

The quantum world blatantly defies intuitions that we've developed while living among relatively large things, like cars, pennies and dust motes. In the quantum world, tiny particles can maintain a special connection over any distance, pass through barriers and simultaneously travel down multiple paths.

A less widely known quantum behavior is dynamical localization, a phenomenon in which a quantum object stays at the same temperature despite a steady supply of energy—bucking the assumption that a cold object will always steal heat from a warmer object.

This assumption is one of the cornerstones of thermodynamics—the study of how heat moves around. The fact that dynamical localization defies this principle means that something unusual is happening in the quantum world—and that dynamical localization may be an excellent probe of where the quantum domain ends and traditional physics begins. Understanding how quantum systems maintain, or fail to maintain, quantum behavior is essential not only to our understanding of the universe but also to the practical development of quantum technologies.

"At some point, the quantum description of the world has to changeover to the classical description that we see, and it's believed that the way this happens is through interactions," says JQI postdoctoral researcher Colin Rylands.

Until now, dynamical localization has only been observed for single quantum objects, which has prevented it from contributing to attempts to pin down where the changeover occurs. To explore this issue, Rylands, together with JQI Fellow Victor Galitski and other colleagues, investigated mathematical models to see if dynamical localization can still arise when many quantum particles interact. To reveal the physics, they had to craft models to account for various temperatures, interaction strengths and lengths of times. The team's results, published in *Physical Review Letters*, suggest that dynamical localization can occur even when strong interactions are part of the picture.

"This result is an example of where a single quantum particle behaves completely differently from a classical particle, and then even with the addition of strong interactions the behavior still resembles that of the quantum particle rather than the classical," says Rylands, who is the first author of the article.

A Quantum Merry-Go-Round

The result extends dynamical localization beyond its single-particle origins, into the regime of many interacting particles. But in order to visualize the effect, it's still useful to start with a single particle. Often, that single particle is discussed in terms of a rotor, which you can picture as a playground merry-go-round (or anything else that spins in a circle). The energy of a rotor (and its temperature) is directly related to how fast it is spinning. And a rotor with a steady supply of energy—one that is given a regular "kick"—is a convenient way of visualizing the differences in the flow of energy in quantum and classical physics.

For example, imagine Hercules tirelessly swiping at a merry-go-round. Most of his swipes will speed it up, but occasionally a swipe will land poorly and slow it down. Under these (imaginary) conditions, a normal merry-go-round would spin faster and faster, building up more and more energy until vibrations finally shake the whole thing apart. This represents how a normal rotor, in theory, can heat up forever without hitting an energy limit.

In the quantum world, things go down differently. For a quantum merry-go-round each swipe doesn't simply increase or decrease the speed. Instead, each swipe produces a quantum superposition over different speeds, representing the chance of finding the rotor spinning at different rates. It's not until you make a measurement that a particular speed emerges from the quantum superposition caused by the preceding kicks.

Previous research, both theoretical and experimental, has shown that at first a quantum rotor doesn't behave very differently from a normal rotor because of this distinction—on average a quantum merry-go-round will also have more energy after experiencing more kicks. But once a quantum rotor has been kicked enough, its speed tends to plateau. After a certain point, the persistent effort of our quantum Hercules fails to increase the quantum merry-go-round's energy (on average).

This behavior is conceptually similar to another thermodynamics-defying quantum phenomenon called Anderson localization. Philip Anderson, one of the founders of condensed-matter physics, earned a Noble Prize for the discovery of the phenomenon. He and his colleagues explained how a quantum particle, like an electron, could become trapped despite many apparent opportunities to move. They explained that imperfections in the arrangement of atoms in a solid can lead to quantum interference among the paths available to a quantum particle, changing the likelihood of it taking each path. In Anderson localization, the chance of being on any path becomes almost zero, leaving the particle trapped in place.

Dynamical localization looks a lot like Anderson localization but instead of getting trapped at a particular position, a particle's energy gets stuck. As a quantum object, a rotor's energy and thus speed are restricted to a set of quantized values. These values form an abstract grid or lattice similar to the locations of atoms in a solid and can produce an interference among energy states similar to the interference among paths in physical space. The probabilities of the different possible energies, instead of the possible paths of a particle, interfere, and the energy and speed get stuck near a single value, despite ongoing kicks.

Exploring a New Quantum Playground

While Anderson localization provided researchers with a perspective to understand a single kicked quantum rotor, it left some ambiguity about what happens to many interacting rotors that can toss energy back and forth. A common expectation was that the extra interactions would allow normal heating by disrupting the quantum balance that limits the increase of energy.

Galitski and colleagues identified a one-dimensional system where they thought the expectation may not hold true. They chose an interacting one-dimensional Bose gas as their playground. In a Bose gas, particles zipping back and forth down a line play the part of the rotors spinning in place. The gas atoms follow the same basic principles as kicked rotors but are more practical to work with in a lab. In labs, lasers can be used to contain the gas and also to cool the atoms in the gas down to a low temperature, which is essential to ensuring a strong quantum behavior.

Once the team selected this playground, they explored mathematical models of the many interacting gas atoms. Exploring the gas at a variety of temperatures, interaction strengths and number of kicks required the team to switch between several different mathematical techniques to get a full picture. In the end their results combined to suggest that when a gas with strong interactions starts near zero temperature it can experience dynamical localization. The team named this phenomenon "many-body dynamical localization."

"These results have important implications and fundamentally demonstrate our incomplete understanding of these systems," says Robert Konik, a coauthor of the paper and physicist at Brookhaven National Lab. "They also contain the seed of possible applications because systems that do not accept energy should be less sensitive to quantum decoherence effects and so might be useful for making quantum computers."

Experimental Support

Of course, a theoretical explanation is only half the puzzle; experimental confirmation is essential to knowing if a theory is on solid ground. Fortunately, an experiment on the opposite coast of the U.S. has been pursuing the same topic. Conversations with Galitski inspired David Weld, an associate physics professor at the University of California, Santa Barbra, to use his team's experimental expertise to probe many-body dynamical localization.

"Usually it's not easy to convince an experimentalist to do an experiment based on theory," says Galitski. "This case was kind of serendipitous, that David already had almost everything ready to go."

Weld's team is using a quantum gas of lithium atoms that is confined by lasers to create an experiment similar to the theoretical model Galitski's team developed. (The main difference is that in the experiment the atoms move in three dimensions instead of just one.)

In the experiment, Weld and his team kick the atoms hundreds of times using laser pulses and repeatedly observe their fate. For different runs of the experiment they tuned the interaction strength of the atoms to different values.

"It's nice because we can go to a noninteracting regime quite perfectly, and that's something that it's pretty easy to calculate the behavior of," says Weld. "And then we can continuously turn up the interaction and move into a regime that's more like what Victor and his coworkers are talking about in this latest paper. And we do observe localization, even in the presence of the strongest interactions that we can add to the system. That's been a surprise to me."

Their preliminary results confirm the prediction that many-body dynamical localization can occur even when strong interactions are part of the picture. This opens new opportunities for researchers to try to pin down the boundary between the quantum and classical world.

"It's nice to be able to show something that people didn't expect and also for it to be experimentally relevant," says Rylands. [14]

Quantum gas reveals first signs of path-bending monopole

Magnets, whether in the form of a bar, horseshoe or electromagnet, always have two poles. If you break a magnet in half, you'll end up with two new magnets, each with its own magnetic north and south.

But some physics theories predict the existence of single-pole magnets—a situation akin to electric charges, which come in either positive or negative chunks. One particular incarnation—called the Yang monopole after its discoverer—was originally predicted in the context of high-energy physics, but it has never been observed.

Now, a team at JQI led by postdoctoral researcher Seiji Sugawa and JQI Fellow Ian Spielman have succeeded in emulating a Yang monopole with an ultracold gas of rubidium atoms. The result, which provides another example of using cold quantum gases to simulate other areas of physics, was reported in the June 29 issue of *Science*.

"This new result links together ideas born in high-energy physics—the Yang monopole—with concepts in condensed matter physics—topological phase transitions—and realizes them in the atomic physics laboratory," Spielman says.

To detect the Yang monopoles in their quantum gas, Spielman, Sugawa and coworkers manipulated the internal compass needles that all atoms carry—a quantum property called spin—using radio waves and microwaves to rotate the needles in specific ways. By cycling the atoms among four different spin orientations, researchers were able to send the atoms on a journey through "spin space" and bring them back to where they started—very much like a traveler on the Earth's surface taking a trip around the globe (but in four dimensions instead of the globe's two).

The team measured the orientation of the atoms' spins after they completed their journey and compared the result to their initial orientations. They found that the atoms' spins didn't return to where they started, a discrepancy that can arise during a trip through curved space . In this case, the size and direction of the deflection matched predictions for the curvature created by a Yang monopole.

To test that the deflections were indeed due to the monopole and not another source, researchers sent the atoms on a different journey, one that attempted to avoid the space-bending singularity created by the monopole. On this new path, the atoms no longer felt an overall tug from the curvature, a strong indication that they had exited the monopole's realm of influence.

Turning the monopole's effects on and off depends only on the big-picture shape of the paths that the atoms take and not on any small wiggles along the way—an indication that the effect is topological. The paths either enclose a monopole or they don't, and this provides a topological feature that could lead to new types of quantum charge pumps, Spielman says. [13]

Destruction of a quantum monopole observed

Scientists at Amherst College (USA) and Aalto University (Finland) have made the first experimental observations of the dynamics of isolated monopoles in quantum matter.

The new study provided a surprise: the quantum monopole decays into another analogue of the magnetic monopole. The obtained fundamental understanding of monopole dynamics may help in the future to build even closer analogues of the magnetic monopoles.

Unlike usual magnets, magnetic monopoles are elementary particles that have only a south or a north magnetic pole, but not both. They have been theoretically predicted to exist, but no convincing experimental observations have been reported. Thus physicists are busy looking for analogue objects.

- In 2014, we experimentally realized a Dirac monopole, that is, Paul Dirac's 80-year-old theory where he originally considered charged quantum particles interacting with a magnetic monopole, says Professor David Hall from Amherst College.

- And in 2015, we created real quantum monopoles, adds Dr. Mikko Möttönen from Aalto University.

Whereas the Dirac monopole experiment simulates the motion of a charged particle in the vicinity of a monopolar magnetic field, the quantum monopole has a point-like structure in its own field resembling that of the magnetic monopole particle itself.

From one quantum monopole to another in less than a second

Now the monopole collaboration led by David Hall and Mikko Möttönen has produced an observation of how one of these unique magnetic monopole analogues spontaneously turns into another in less than a second.

- Sounds easy but we actually had to improve the apparatus to make it happen, says Mr. Tuomas Ollikainen who is the first author of the new work.

The scientists start with an extremely dilute gas of rubidium atoms chilled near absolute zero, at which temperature it forms a Bose-Einstein condensate. Subsequently, they prepare the system in a non-magnetized state and ramp an external magnetic-field zero point into the condensate thus creating an isolated quantum monopole. Then they hold the zero point still and wait for the system to gradually magnetize along the spatially varying magnetic field. The resulting destruction of the quantum monopole gives birth to a Dirac monopole.

- I was jumping in the air when I saw for the first time that we get a Dirac monopole from the decay. This discovery nicely ties together the monopoles we have been producing over the years, says Dr. Möttönen.

Beyond Nobel physics

The quantum monopole is a so-called topological point defect, that is, a single point in space surrounded by a structure in the non-magnetized state of the condensate that cannot be removed by continuous reshaping. Such structures are related to the 2016 Nobel Prize in Physics which was awarded in part for discoveries of topological phase transitions involving quantum whirlpools, or vortices.

- Vortex lines have been studied experimentally in superfluids for decades; monopoles, on the other hand, have been studied experimentally for just a few years, says Prof. Hall.

Although its topology protects the quantum monopole, it can decay since the whole phase of matter changes from non-magnetized to magnetized.

- No matter how robust an ice sculpture you make, it all flows down the drain when the ice melts, says Mr. Ollikainen.

- For the first time, we observed spontaneously appearing Dirac monopoles and the related vortex lines, says Dr. Möttönen. [12]

Physics Professor David Hall and Team Observe Quantum-Mechanical Monopoles

An artistic illustration of a quantum-mechanical monopole.

Hall and Ray manipulated a gas of rubidium atoms prepared in a nonmagnetic state near absolute zero temperature in an atomic refrigerator in Hall's lab in Amherst's Merrill Science Center. Under these extreme conditions, they were able to create monopoles in the quantum field of the ultracold gas.

"In this nonmagnetic state, a structure was created in the field describing the gas resembling the magnetic monopole particle as described in grand unified theories of particle physics," said Aalto University (Finland) Academy Research Fellow Mikko Möttönen, a collaborator on the team who led the theoretical analysis of the monopole. "Previously, we have used the gas to detect a monopole within a so-called synthetic magnetic field, but there has been no monopole in the quantum field describing the gas itself. Now we have finally witnessed the quantum-mechanical monopole."

Ordinarily, magnetic poles come in pairs: each magnet has both a north pole and a south pole. As the name suggests, however, a magnetic monopole is a magnetic particle possessing only a single, isolated pole—a north pole without a south pole, or vice versa. Despite extensive experimental searches, in everything from lunar samples (moon rock) to ancient fossilized minerals, no observation of a naturally occurring magnetic monopole has yet been confirmed.

In this case, the gas is in a nonmagnetic state, and no quantum whirlpools or monopoles are created in the synthetic magnetic field, Möttönen continued. However, quantum-mechanical magnetic order prevailed in the sample itself, and the team was able to manipulate it with adjustments to an externally applied magnetic field to generate the quantum-mechanical monopoles.

"In the experiment, the control of those magnetic fields must be stable to a small fraction of the size of the Earth's magnetic field," said Hall. "The main experimental challenge we faced was to prepare the ultracold gas under highly sensitive conditions, in which field fluctuations due to the motion of metal objects or power-line variations can make observation of the monopoles difficult."

The team's result is further evidence that quantum-mechanical monopole structures do exist in nature, he said, even if magnetic monopoles themselves remain at large.

A 1991 Amherst graduate, Hall is an experimental physicist specializing in Bose-Einstein condensation. He received A.M. and Ph.D. degrees from Harvard University and did postgraduate work at the University of Colorado. [11]

Probably there is a quantum entanglement between two monopoles, giving together a magnetic dipole?!

Quantum interference links the fate of two atoms

For the first time, physicists from the CNRS and Université Paris-Sud at the Laboratoire Charles Fabry (CNRS/Institut d'Optique Graduate School) have achieved interference between two separate atoms: when sent towards the opposite sides of a semi-transparent mirror, the two atoms always emerge together. This type of experiment, which was carried out with photons around thirty years ago, had so far been impossible to perform with matter, due to the extreme difficulty of creating and manipulating pairs of indistinguishable atoms. The work is published in the journal Nature dated 2 April 2015.

The notion of indistinguishable particles (1), mentioned as early as 1924 by Bose and Einstein, lies at the heart of some of the most perplexing features of quantum mechanics. One such emblematic feature, observed experimentally nearly 30 years ago by Hong, Ou and Mandel, involves photons and a semi-transparent mirror (when a photon is sent towards either side of the mirror, it has a fifty percent chance of passing through it and the same percentage chance of being reflected). If two identical photons are sent towards opposite sides of the mirror, they can be seen to emerge from one side or the other, but always together. In other words, it appears impossible for the two photons to go their own separate ways.

Now, for the first time, physicists at the Laboratoire Charles Fabry have demonstrated this phenomenon with particles of matter, namely helium-4 atoms, instead of particles of light. By combining pairs of atoms on the equivalent (for matter) of a semi-transparent mirror (2), the researchers observed that when two identical atoms arrive at the same time they always emerge together, just as photons do. This result is the irrefutable signature of destructive quantum interference: the process in which two atoms are simultaneously reflected, and the one in which they are simultaneously transmitted, cancel each other out.

The main obstacle that the researchers managed to overcome was that of creating pairs of indistinguishable atoms and manipulating them. To do this, they first produced a Bose-Einstein condensate (3) containing around 100,000 atoms of helium-4. They succeeded in controlling collisions between the particles so as to produce pairs of indistinguishable atoms, which emerged from this very cold gas at an average rate of one every 30 seconds. The team then manipulated the atoms using laser beams in order to achieve the equivalent of the optical setup in the experiment that Hong, Ou and Mandel performed with photons. To characterize the effect of interference, the researchers staggered the moment of arrival of the two atoms at opposite sides of the mirror. After tens of hours of recording, they were able to verify that, when the two arrivals are separated by more than about a hundred microseconds, each atom goes its own way, whereas when arrivals are closer together they tend to emerge from the same side. The effect is at a maximum when the atoms arrive simultaneously.

As well as confirming a surprising prediction of quantum mechanics, the experiment demonstrates the tremendous progress achieved in recent years in controlling sources of atoms at the quantum scale. Thanks to the extremely sophisticated manipulation of pairs of atoms, this work demonstrates their potential for application in the field of quantum information, which consists in using the specific characteristics of quantum physics for more efficient processing and more secure communication of information.

1 Indistinguishable particles are particles that are strictly identical and in exactly the same state (for instance, having the same speed and, for photons, identical wavelength and polarization).

2 A Bragg mirror, i.e. a light wave from which atoms can rebound.

3 A Bose-Einstein condensate is a gas cooled to a very low temperature, in which atoms 'condense': they no longer display random motion in all directions, and progressively enter the same quantum state. Since they lose their individual nature, they are described as a single macroscopic object, described by a single wave function. [10]

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]

Quantum Biology

The human body is a constant flux of thousands of chemical/biological interactions and processes connecting molecules, cells, organs, and fluids, throughout the brain, body, and nervous system. Up until recently it was thought that all these interactions operated in a linear sequence, passing on information much like a runner passing the baton to the next runner. However, the latest findings in quantum biology and biophysics have discovered that there is in fact a tremendous degree of coherence within all living systems.

Quantum Consciousness

Extensive scientific investigation has found that a form of quantum coherence operates within living biological systems through what is known as biological excitations and biophoton emission. What this means is that metabolic energy is stored as a form of electromechanical and electromagnetic excitations. These coherent excitations are considered responsible for generating and maintaining long-range order via the transformation of energy and very weak electromagnetic signals. After nearly twenty years of experimental research, Fritz-Albert Popp put forward the hypothesis that biophotons are emitted from a coherent electrodynamics field within the living system.

What this means is that each living cell is giving off, or resonating, a biophoton field of coherent energy. If each cell is emitting this field, then the whole living system is, in effect, a resonating field-a ubiquitous nonlocal field. And since biophotons are the entities through which the living system communicates, there is near-instantaneous intercommunication throughout. And this, claims Popp, is the basis for coherent biological organization -- referred to as quantum coherence. This discovery led Popp to state that the capacity for evolution rests not on aggressive struggle and rivalry but on the capacity for communication and cooperation. In this sense the built-in capacity for species evolution is not based on the individual but rather living systems that are interlinked within a coherent whole: Living systems are thus neither the subjects alone, nor objects isolated, but both subjects and objects in a mutually communicating universe of meaning. . . . Just as the cells in an organism take on different tasks for the whole, different populations enfold information not only for themselves, but for all other organisms, expanding the consciousness of the whole, while at the same time becoming more and more aware of this collective consciousness.

Quantum Cognition

Human Perception

A Bi-stable perceptual phenomenon is a fascinating topic in the area of perception. If a stimulus has an ambiguous interpretation, such as a Necker cube, the interpretation tends to oscillate across time. Quantum models have been developed to predict the time period between oscillations and how these periods change with frequency of measurement. Quantum theory has also been used for modeling Gestalt perception, to account for interference effects obtained with measurements of ambiguous figures. [6]

Human memory

The hypothesis that there may be something quantum-like about the human mental function was put forward with “Spooky Activation at Distance” formula which attempted to model the effect that when a word’s associative network is activated during study in memory experiment, it behaves like a quantum-entangled system. Models of cognitive agents and memory based on quantum collectives have been proposed by Subhash Kak. But he also points to specific problems of limits on observation and control of these memories due to fundamental logical reasons. [6]

Knowledge representation

Concepts are basic cognitive phenomena, which provide the content for inference, explanation, and language understanding. Cognitive psychology has researched different approaches for understanding concepts including exemplars, prototypes, and neural networks, and different fundamental problems have been identified, such as the experimentally tested non classical behavior for the conjunction and disjunction of concepts, more specifically the Pet-Fish problem or guppy effect, and the overextension and under extension of typicality and membership weight for conjunction and disjunction. By and large, quantum cognition has drawn on quantum theory in three ways to model concepts.

Exploit the contextuality of quantum theory to account for the contextuality of concepts in cognition and language and the phenomenon of emergent properties when concepts combine.

Use quantum entanglement to model the semantics of concept combinations in a nondecompositional way, and to account for the emergent properties/associates/inferences in relation to concept combinations.

Use quantum superposition to account for the emergence of a new concept when concepts are combined, and as a consequence put forward an explanatory model for the Pet-Fish problem situation, and the overextension and under extension of membership weights for the conjunction and disjunction of concepts. The large amount of data collected by Hampton on the combination of two concepts can be modeled in a specific quantum-theoretic framework in Fock space where the observed deviations from classical set (fuzzy set) theory, the above mentioned over- and under-extension of membership weights, are explained in terms of contextual interactions, superposition, interference, entanglement and emergence. And, more, a cognitive test on a specific concept combination has been performed which directly reveals, through the violation of Bell’s inequalities, quantum entanglement between the component concepts. [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." [9]

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]

Dark Matter and Energy

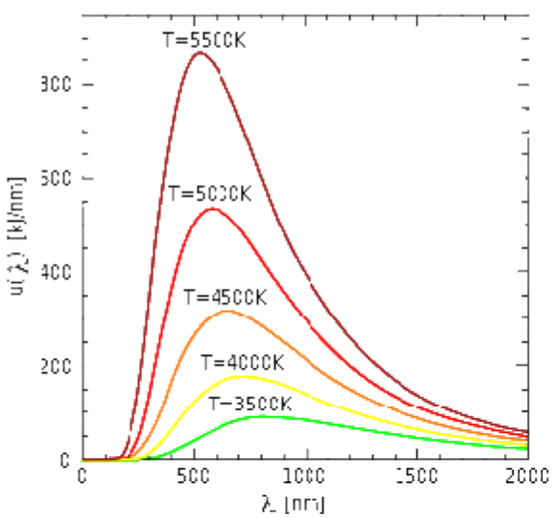
Dark matter is a type of matter hypothesized in astronomy and cosmology to account for a large part of the mass that appears to be missing from the universe. Dark matter cannot be seen directly with telescopes; evidently it neither emits nor absorbs light or other electromagnetic radiation at any significant level. It is otherwise hypothesized to simply be matter that is not reactant to light. Instead, the existence and properties of dark matter are inferred from its gravitational effects on visible matter, radiation, and the large-scale structure of the universe. According to the Planck mission team, and based on the standard model of cosmology, the total mass–energy of the known universe contains 4.9% ordinary matter, 26.8% dark matter and 68.3% dark energy. Thus, dark matter is estimated to constitute 84.5% of the total matter in the universe, while dark energy plus dark matter constitute 95.1% of the total content of the universe. [6]

Cosmic microwave background

The cosmic microwave background (CMB) is the thermal radiation assumed to be left over from the "Big Bang" of cosmology. When the universe cooled enough, protons and electrons combined to form neutral atoms. These atoms could no longer absorb the thermal radiation, and so the universe became transparent instead of being an opaque fog. [7]

Thermal radiation

Thermal radiation is electromagnetic radiation generated by the thermal motion of charged particles in matter. All matter with a temperature greater than absolute zero emits thermal radiation. When the temperature of the body is greater than absolute zero, interatomic collisions cause the kinetic energy of the atoms or molecules to change. This results in charge-acceleration and/or dipole oscillation which produces electromagnetic radiation, and the wide spectrum of radiation reflects the wide spectrum of energies and accelerations that occur even at a single temperature. [8]



Conclusions

The development—explored in a paper published in Science—is a remarkable step forward in quantum research. A better understanding of the structure of monopoles and other topological entities is very valuable to scientists, in part because they appear in the models describing the first moments of the universe's existence and affect the properties of many different materials, such as metals.

"This was a very exciting experiment to perform," says former Amherst postdoctoral research associate Michael Ray, now a visiting assistant professor at Union College and the lead author of the paper. "These kinds of defects are relevant to theories that describe the early universe, so observing this monopole gives us a glimpse into those moments but on a much more accessible scale." [11] Probably there is a quantum entanglement between two monopoles, giving together a magnetic dipole?!

For the first time, physicists have achieved interference between two separate atoms: when sent towards the opposite sides of a semi-transparent mirror, the two atoms always emerge together. This type of experiment, which was carried out with photons around thirty years ago, had so far been impossible to perform with matter, due to the extreme difficulty of creating and manipulating pairs of indistinguishable atoms. [10]

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

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]

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 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. 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. The lower energy side has no compensating intensity level, it is the dark

energy and the corresponding matter is the dark matter. Since the dark matter not participating in the diffraction patterns, also cannot be part of quantum entanglement, because of this we haven't information about it, we conclude its existence from its gravitational effect only.

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