

Quantum Nonlocal Causality

Quantum mechanics wreaks even more havoc with conventional ideas of causality than some have suspected – according to a team of researchers based in Australia, with collaborators in Scotland and Germany. They have shown that even allowing causality to be nonlocal – so that an event in one place can have an influence on another, distant place – is not enough to explain how quantum objects behave. [13]

A research team led by a Heriot-Watt scientist has shown that the universe is even weirder than had previously been thought. Quantum correlations do not imply instant causation. [12]

Quantum systems are extremely hard to analyze if they consist of more than just a few parts. It is not difficult to calculate a single hydrogen atom, but in order to describe an atom cloud of several thousand atoms, it is usually necessary to use rough approximations. The reason for this is that quantum particles are connected to each other and cannot be described separately. [11]

Quantum coherence and quantum entanglement are two landmark features of quantum physics, and now physicists have demonstrated that the two phenomena are "operationally equivalent"—that is, equivalent for all practical purposes, though still conceptually distinct. This finding allows physicists to apply decades of research on entanglement to the more fundamental but less-well-researched concept of coherence, offering the possibility of advancing a wide range of quantum technologies. [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 ratio 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 large-scale 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 Δx and Δp uncertainty.

Quantum mechanics trumps nonlocal causality

Quantum mechanics wreaks even more havoc with conventional ideas of causality than some have suspected – according to a team of researchers based in Australia, with collaborators in Scotland and Germany. They have shown that even allowing causality to be nonlocal – so that an event in one place can have an influence on another, distant place – is not enough to explain how quantum objects behave.

Without cause and effect, science would be impossible. You could never use an observation to deduce anything about the underlying mechanism that caused it. But quantum mechanics challenges our commonsense picture of causality – for example by implying that some things happen at random, with no apparent cause, or that an action in one place can seem to have an effect elsewhere, even if the two locations cannot interact.

This kind of nonlocality has become widely accepted in quantum theory, thanks to experiments on so-called entangled states. Here two or more quantum entities, such as photons of light, acquire interdependent properties, revealed by correlations in the measured values of their properties. For example, pairs of polarized photons can be entangled so that, if one has horizontal polarization, the other has vertical polarization.

Action at a distance?

Because quantum properties have inherent randomness, these correlations are typically revealed in averages of many measurements. The twist is that quantum mechanics seems to insist that these properties are not fixed until they are measured. This seems to imply that a measurement on one entangled photon affects the other instantaneously across space.

Perhaps quantum mechanics is incomplete, though, and the properties were actually fixed within the particles all along. This "local realist" picture, in which quantum particles have intrinsic, localized properties even if we can't see them directly, was assumed by Albert Einstein and colleagues in 1935 when they argued that such instant action at a distance creates a paradox for quantum mechanics.

But after Northern Irish physicist John Bell showed in 1964 how to distinguish between the predictions of local realism and those of quantum mechanics, numerous experiments have shown that the quantum picture seems to be correct. There's no real instantaneous action at a distance, because we can't think of the measurement on one particle as "causing" some "effect" on the other.

Painting a realist picture

It's still possible, however, to explain Bell-type tests of quantum correlations in a "realist" picture (where quantum objects possess fixed properties before measurement) if other of his assumptions are rejected. If, say, causation itself were nonlocal, so that an intervention in one place is felt elsewhere, then a measurement on one photon might directly influence that on the other, creating the correlation between them.

The new experiments, says Martin Ringbauer of the University of Queensland, who led the Australian group, "consider this class of realist models, where Bell's central assumption of local causality is relaxed."

To test whether a realist but nonlocally causal model is able to explain quantum phenomena, the team devised Bell-type experiments where such a model makes different predictions from quantum mechanics. First they performed a modified version of one of the earliest such experiments on entangled photons in the 1970s, called a Clauser-Horne-Shimony-Holt (CHSH) test.

Causality, not correlation

To test for causal effects and not just correlation in this test, they did not simply make passive measurements of photon polarization but actively intervened to change the outcome. "Imagine you are watching someone flick a light switch and observe that the light goes on and off in perfect correlation", says Ringbauer. "You can't tell whether the switch causes the light to go on, or the light going on causes the person to flick the switch, or there is some hidden common cause that is responsible for both the light going on and the person flicking the switch."

However, if you're in control of the switch yourself, you can tell the difference. In their experiment, Ringbauer and colleagues fixed the outcome of measurement on one photon by inserting optical devices that affected its polarization before the measurement was made. They then looked for a concurrent change in the statistics of the other. Because they saw none, they concluded that there could be no nonlocal causality at play in which measurement outcomes on one photon could cause changes in those on the other.

The team then did a more complicated experiment involving three possible measurement settings as opposed to just two for the CHSH experiment. This allowed them to verify that their conclusions are independent of the specific apparatus used to do the tests. In other words, the results do not depend on any particular type of intervention.

Radical revisions

The only way now that one might rescue some kind of classical (realist) causal interpretation of quantum correlations involves more radical revisions of Bell's assumptions, says Ringbauer – for example, backwards-in-time causation or a "many-worlds" interpretation of quantum mechanics with multiple parallel universes.

Caslav Brukner, a quantum theorist at the University of Vienna, told physicsworld.com: "I like the work since it excludes a large class on nonlocal causal theories."

Previous tests looked only at a very specific version of such theories, he adds.

The experiment "is not only important from the perspective of quantum foundations, but might also have implications in quantum cryptography," says Ognjan Oreshkov of the Free University of Brussels in Belgium – for example in cases where one can't guarantee that the measurements made by the sender and receiver are kept secret.

The research is described in Science Advances. [13]

Quantum correlations do not imply instant causation

A research team led by a Heriot-Watt scientist has shown that the universe is even weirder than had previously been thought.

In 2015 the universe was officially proven to be weird. After many decades of research, a series of experiments showed that distant, entangled objects can seemingly interact with each other through what Albert Einstein famously dismissed as "Spooky action at a distance".

A new experiment by an international team led by Heriot-Watt's Dr Alessandro Fedrizzi has now found that the universe is even weirder than that: entangled objects do not cause each other to behave the way they do.

Distinguishing cause from effect comes naturally to us. Picture yourself in a room where someone is flicking a light switch. Intuition and experience lets you establish a simple causal model: the switch causes the lights to turn on and off. In this case, correlation implies causation.

If we could entangle two lights, you would see them turn on and off at random, regardless of how far apart they are, with no obvious switch and in perfect lockstep.

Einstein's preferred explanation of this mysterious effect was that there must be a hidden light switch which acts as a common cause for our entangled lights.

Einstein's world view was finally proven wrong last year by groups in Vienna, Delft and Boulder. However, the search for an answer how entanglement really works continues, and one popular explanation was that entangled objects could cause each other perhaps instantaneously, ignoring the universal speed-of-light limit.

In a new experiment, Dr Fedrizzi and colleagues found that this claim is also wrong. They set up individual photons to act like entangled light bulbs and then subjected them to two tests.

In the first, they essentially flicked the light switch themselves to test their causal hypothesis. In the second, they tested a new inequality by theory collaborator Rafael Chaves, which shows that nonlocal causality can in general not explain quantum entanglement.

'Spooky' action

"We have spent decades to prove Einstein wrong and can now start looking into extended models of his 'spooky' action", says Dr Fedrizzi. "What we found is yet another mechanism that doesn't explain this quintessential feature of entanglement. Our results drastically narrow down the remaining explanations."

The techniques the team developed also have practical applications such as in cyber-security. They can for example be used to increase the level of trust we have into quantum encryption devices. [12]

Solving hard quantum problems: Everything is connected

Quantum systems are extremely hard to analyse if they consist of more than just a few parts. It is not difficult to calculate a single hydrogen atom, but in order to describe an atom cloud of several thousand atoms, it is usually necessary to use rough approximations. The reason for this is that quantum particles are connected to each other and cannot be described separately. Kaspar Sakmann (TU Wien, Vienna) and Mark Kasevich (Stanford, USA) have now shown in an article published in Nature Physics ("Single-shot simulations of dynamic quantum many-body systems") that this problem can be overcome. They succeeded in calculating effects in ultra-cold atom clouds which can only be explained in terms of the quantum correlations between many atoms. Such atom clouds are known as Bose-Einstein condensates and are an active field of research.

Quantum Correlations

Quantum physics is a game of luck and randomness. Initially, the atoms in a cold atom cloud do not have a predetermined position. Much like a die whirling through the air, where the number is yet to be determined, the atoms are located at all possible positions at the same time. Only when they are measured, their positions are fixed. "We shine light on the atom cloud, which is then absorbed by the atoms", says Kaspar Sakmann. "The atoms are photographed, and this is what determines their position. The result is completely random."

There is, however, an important difference between quantum randomness and a game of dice: if different dice are thrown at the same time, they can be seen as independent from each other. Whether or not we roll a six with die number one does not influence the result of die number seven. The atoms in the atom cloud on the other hand are quantum physically connected. It does not make sense to analyse them individually, they are one big quantum object. Therefore, the result of every position measurement of any atom depends on the positions of all the other atoms in a mathematically complicated way.

"It is not hard to determine the probability that a particle will be found at a specific position", says Kaspar Sakmann. "The probability is highest in the centre of the cloud and gradually diminishes towards the outer fringes." In a classically random system, this would be all the information that is needed. If we know that in a dice roll, any number has the probability of one sixth, then we can also determine the probability of rolling three ones with three dice. Even if we roll five ones consecutively, the probability remains the same the next time. With quantum particles, it is more complicated than that.

"We solve this problem step by step", says Sakmann. "First we calculate the probability of the first particle being measured on a certain position. The probability distribution of the second particle depends on where the first particle has been found. The position of the third particle depends on the first two, and so on." In order to be able to describe the position of the very last particle, all the other positions have to be known. This kind of quantum entanglement makes the problem mathematically extremely challenging.

Only Correlations Can Explain the Experimental Data

But these correlations between many particles are extremely important - for example for calculating the behaviour of colliding Bose-Einstein-condensates. "The experiment shows that such collisions can lead to a special kind of quantum waves. On certain positions we find many particles, on an adjacent position we do not find any", says Kaspar Sakmann. "If we consider the atoms separately, this cannot be explained. Only if we take the full quantum distribution into account, with all its higher correlations, these waves can be reproduced by our calculations."

Also other phenomena have been calculated with the same method, for instance Bose-Einstein-condensates which are stirred with a laser beam, so that little vortices emerge - another typical quantum many-particle-effect. "Our results show how important these correlations are and that it is possible to include them in quantum calculations, in spite of all mathematical difficulties", says Sakmann. With certain modifications, the approach can be expected to be useful for many other quantum systems as well. [11]

Physicists find quantum coherence and quantum entanglement are two sides of the same coin

Quantum coherence and quantum entanglement are two landmark features of quantum physics, and now physicists have demonstrated that the two phenomena are "operationally equivalent"—that is, equivalent for all practical purposes, though still conceptually distinct. This finding allows physicists to apply decades of research on entanglement to the more fundamental but less-well-researched concept of coherence, offering the possibility of advancing a wide range of quantum technologies.

Close relatives with the same roots

Although physicists have known that coherence and entanglement are close relatives, the exact relationship between the two resources has not been clear.

It's well-known that quantum coherence and quantum entanglement are both rooted in the superposition principle—the phenomenon in which a single quantum state simultaneously consists of multiple states—but in different ways. Quantum coherence deals with the idea that all objects have wave-like properties. If an object's wave-like nature is split in two, then the two waves may coherently interfere with each other in such a way as to form a single state that is a superposition of the two states. This concept of superposition is famously represented by Schrödinger's cat, which is both dead and alive at the same time when in its coherent state inside a closed box. Coherence also lies at the heart of quantum computing, in which a qubit is in a superposition of the "0" and "1" states, resulting in a speed-up over various classical algorithms. When such a state experiences decoherence, however, all of its quantumness is typically lost and the advantage vanishes.

The second phenomenon, quantum entanglement, also involves superposition. But in this case, the states in a superposition are the shared states of two entangled particles rather than those of the two split waves of a single particle. The intrigue of entanglement lies in the fact that the two

entangled particles are so intimately correlated that a measurement on one particle instantly affects the other particle, even when separated by a large distance. Like coherence, quantum entanglement also plays an essential role in quantum technologies, such as quantum teleportation, quantum cryptography, and super dense coding.

Converting one to the other

In a paper to be published in *Physical Review Letters*, physicists led by Gerardo Adesso, Associate Professor at the University of Nottingham in the UK, with coauthors from Spain and India, have provided a simple yet powerful answer to the question of how these two resources are related: the scientists show that coherence and entanglement are quantitatively, or operationally, equivalent, based on their behavior arising from their respective resource theories.

The physicists arrived at this result by showing that, in general, any nonzero amount of coherence in a system can be converted into an equal amount of entanglement between that system and another initially incoherent one. This discovery of the conversion between coherence and entanglement has several important implications. For one, it means that quantum coherence can be measured through entanglement. Consequently, all of the comprehensive knowledge that researchers have obtained about entanglement can now be directly applied to coherence, which in general is not nearly as well-researched (outside of the area of quantum optics). For example, the new knowledge has already allowed the physicists to settle an important open question concerning the geometric measure of coherence: since the geometric measure of entanglement is a "full convex monotone," the same can be said of the associated coherence measure. As the scientists explained, this is possible because the new results allowed them to define and quantify one resource in terms of the other.

"The significance of our work lies in the fact that we prove the close relation between entanglement and coherence not only qualitatively, but on a quantitative level," coauthor Alex Streltsov, of ICFO-The Institute of Photonic Sciences in Barcelona, told *Phys.org*. "More precisely, we show that any quantifier of entanglement gives rise to a quantifier of coherence. This concept allowed us to prove that the geometric measure of coherence is a valid coherence quantifier, thus answering a question left open in several previous works."

While the results show that coherence and entanglement are operationally equivalent, the physicists explain that this doesn't mean that are the exact same thing, as they are still conceptually different ideas.

"Despite having the same roots of origin, namely quantum superposition, coherence and entanglement are conceptually different," said coauthors Uttam Singh, Himadri Dhar, and Manabendra Bera at the Harish-Chandra Research Institute in Allahabad, India. "For example, coherence can be present in single quantum systems, where entanglement is not well-defined. Also, coherence is defined with respect to a given basis, while entanglement is invariant under local basis changes. In all, we believe coherence and entanglement are operationally equivalent but conceptually different."

Future quantum connections

The operational equivalence of coherence and entanglement will likely have a far-reaching impact on areas ranging from quantum information theory to more nascent fields such as quantum biology and nanoscale thermodynamics. In the future, the physicists plan to investigate whether coherence

and entanglement might also be interconverted into a third resource—that of quantum discord, which, like entanglement, is another type of quantum correlation between two systems.

"Our future plans are diverse," Adesso said. "On the theoretical side, we are working to construct a unified framework to interpret, classify and quantify all different forms of quantum resources, including and beyond entanglement and coherence, and highlight the interlinks among them from an operational perspective. This will allow us to navigate the hierarchy of quantumness indicators in composite systems with a common pilot, and to appreciate which particular ingredients are needed in various informational tasks.

"On the practical side, we are investigating experimentally friendly schemes to detect, quantify, and preserve coherence, entanglement and other quantum correlations in noisy environments. More fundamentally, we hope these results will inspire us to devise scalable and efficient methods to convert between different quantum resources for technological applications, and bring us closer to understanding where the boundaries of the quantum world ultimately lie in realistic scenarios." [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 electrodynamic 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 unfold 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 non-decompositional 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 Δx position difference and with a Δp momentum difference such a way that they product is about the half Planck reduced constant. For the proton this Δx much less in the nucleon, than in the orbit of the electron in the atom, the Δp 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 Δx position with Δp 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 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 1/2 spin creator particle to make equal the spins of the weak interaction, for example neutron decay to 2 fermions, every particle is fermions with 1/2 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 $\frac{1}{2}$ 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 than 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 $E = h\nu$ and $E = mc^2$, $m = h\nu / c^2$ that is the m depends only on the ν frequency. It means that the mass of the proton and electron are electromagnetic and the result of the electromagnetic induction, caused by the changing acceleration of the spinning and moving charge! It could be that the m_0 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 Big 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 ratio $M_p=1840 M_e$. 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.

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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

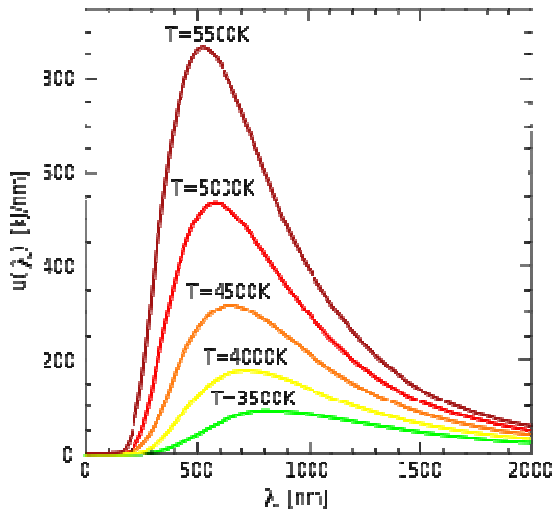
Dark matter is a type of matter hypothesized in astronomy and cosmology to account for a large part of the mass that appears to be missing from the universe. Dark matter cannot be seen directly with telescopes; evidently it neither emits nor absorbs light or other electromagnetic radiation at any significant 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 operational equivalence of coherence and entanglement will likely have a far-reaching impact on areas ranging from quantum information theory to more nascent fields such as quantum biology and nanoscale thermodynamics. In the future, the physicists plan to investigate whether coherence and entanglement might also be interconverted into a third resource—that of quantum discord, which, like entanglement, is another type of quantum correlation between two systems. [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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