Hidden Order in Disorder

Researchers of Karlsruhe Institute of Technology (KIT) and colleagues from several countries have now found that in amorphous, i.e. disordered, systems, optimization of the individual cells gradually results in the same structure, although it remains amorphous. [18]

Understanding how these materials mix has implications in industries such as pharmaceuticals and concrete manufacturing, but little is still known about how to best mix them. [17]

The scientists identified a shortlist, a kind of "periodic table" of the most designable knot types, i.e. those knots that could easily self-assemble under appropriate physical and chemical conditions. [16]

Scientists have now observed for the first time how diamonds grow from seed at an atomic level, and discovered just how big the seeds need to be to kick the crystal growing process into overdrive. [15]

The researchers engineered diamond strings that can be tuned to quiet a qubit's environment and improve memory from tens to several hundred nanoseconds, enough time to do many operations on a quantum chip. [14]

Intel has announced the design and fabrication of a 49-qubit superconducting quantum-processor chip at the Consumer Electronics Show in Las Vegas.

To improve our understanding of the so-called quantum properties of materials, scientists at the TU Delft investigated thin slices of $SrIrO_3$, a material that belongs to the family of complex oxides. [12]

New research carried out by CQT researchers suggest that standard protocols that measure the dimensions of quantum systems may return incorrect numbers. [11]

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

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

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

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

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

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

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

Contents

Author: George Rajna

Preface

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

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

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

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

Order hidden in disorder

Partitioning space into cells with optimum geometrical properties is a central challenge in many fields of science and technology. Researchers of Karlsruhe Institute of Technology (KIT) and colleagues from several countries have now found that in amorphous, i.e. disordered, systems, optimization of the individual cells gradually results in the same structure, although it remains amorphous. The disordered structure quickly converges to hyperuniformity, a hidden order on large scales. This is reported in *Nature Communications*.

Science research often entails the search for an optimum foam or for a method to pack spheres as closely as possible. The ideal tessellation of three-dimensional space has been studied for a long time by scientists. It is not only of theoretical interest, but relevant to many practical applications, among others for telecommunications, image processing, or complex granules. Researchers of KIT's Institute of Stochastics have now studied a special problem of tessellation, the quantizer problem. "The goal is to partition space into cells, and all points in a cell to be located as closely as possible to the cell center, intuitively speaking," says Dr. Michael Andreas Klatt, former staff member of the Institute, who now works at Princeton University in the U.S. Solutions of the quantizer problem can be used for the development of novel materials and may contribute to a better understanding of the unique properties of complex cell tissue in future.

The theoretical work combines methods of stochastic geometry and statistical physics, and is now reported in *Nature Communications*. The researchers of KIT, Princeton University, Friedrich-Alexander-Universität (FAU) Erlangen-Nuremberg, Ruđer Bošković Institute in Zagreb, and Murdoch University in Perth used the so-called Lloyd algorithm, a method to partition space into uniform regions. Every region has exactly one center and contains those points in space that are closer to this than to any other center. Such regions are referred to as Voronoi cells. The Voronoi diagram is made up of all points having more than one closest center and, hence, forming the boundaries of the regions.

The scientists studied stepwise local optimization of various point patterns and found that all completely amorphous, i.e. disordered, states do not only remain completely amorphous, but that the initially diverse processes converge to a statistically indistinguishable ensemble. Stepwise local optimization also rapidly compensates extreme global fluctuations of density. "The resulting structure is nearly hyperuniform. It does not exhibit any obvious, but a hidden order on large scales," Klatt says.

Hence, this order hidden in amorphous systems is universal, i.e. stable and independent of properties of the initial state. This provides basic insight into the interaction of order and disorder and can be used among others for the development of novel materials. Of particular interest are photonic metamaterials similar to a semiconductor for light or so-called block copolymers, i.e. nanoparticles composed of longer sequences or blocks of various molecules that form regular and complex structures in a self-organized way. [18]

When mixing granular matter, order among disorder

Mixing liquids is easy, or at least scientifically understood: a drop of food coloring will eventually mix into a cup of water through diffusion, and a dollop of cream can be mixed into coffee with a spoon through what is called turbulent mixing.

But what if the material has the properties of both liquids and solids, which is the case for materials like concrete, paint, and sand? Called yield stress materials, these mixtures can both flow like liquids and remain still like solids.

Understanding how these materials mix has implications in industries such as pharmaceuticals and concrete manufacturing, but little is still known about how to best mix them.

In a new paper in *Nature Communications*, Northwestern Engineering professors find that mixing yield stress materials creates both mixed and non-mixed regions, providing a fundamental beginning to understanding how to best design mixing protocols. Julio M. Ottino, Paul Umbanhowar, and Richard Lueptow served as the paper's co-authors.

"The theoretical foundations of flow of granular matter are still very incomplete," said Ottino, Walter P. Murphy Professor of Chemical and Biological Engineering. "We found remarkable persistence of order amid chaos."

In question was how well granular material could be mixed in a basic system: a spherical tumbler. Would the material mix like a solid, through a "cutting-and-shuffling" method similar to a deck of cards? Or would it mix like a viscous liquid, like honey, through a "stretching-and-folding" pattern?

To test this idea, the researchers half-filled a spherical tumbler with 2 millimeter-sized glass beads. When rotated, the top layer of beads flowed like a fluid down to the bottom of the sphere, while the other beads remained in place, like a solid.

But researchers mixed the beads by rotating the tumbler along different axes. To track how well the beads mixed, they placed a 4 mm tracer particle inside and then ran the rotations over and over, sometimes up to 500 times, and took X-ray images of the sphere to see where the tracer particle ended up.

Despite trying several different rotational protocols, the researchers found that there were inevitably regions that mixed and regions that did not mix. This was the result of the interplay between the two mixing methods, cutting-and-shuffling and stretching-and-folding.

"Even though the material often moves in wedges in this cutting-and-shuffling manner, all those wedges do is move around together," said Umbanhowar, research professor of mechanical engineering. "There are regions that never get mixed."

Understanding this concept may lead to insights in interesting and unexpected places, such as the Spanish Christmas Lottery, where 100,000 small wooden balls with unique ticket numbers are tumbled in one sphere, while 1,807 balls labeled with prizes are tumbled in another. During the drawing, one prize ball and one corresponding ticket number are plucked from each sphere until the prize ball sphere is empty. But if the tumbler includes regions that are mixed and regions that aren't, the ball's initial placement in the tumbler becomes an outsized factor in whether it will be chosen.

"There is an expectation of randomness, but our results show that this is not the case," Ottino said.

The researchers hope to conduct future studies to show how this information can be applied across different materials.

"This gives us a whole new tool to understand what mixes and what doesn't mix," Umbanhowar said. "These results can ultimately be used as a design tool." [17]

A periodic table of molecular knots

Consider a short piece of rope—could you guess which knots are more likely to form if you crumple and shake it? Synthetic chemists have long been working on a molecular version of this problem, and so far, have succeeded at synthesizing a half-dozen knot types using molecular self-assembling techniques. But which other knot types could be realised in the future? This is the challenging question that SISSA scientists, in association with the University of Padua, have tackled using computer simulations in this new work published in *Nature Communications*.

The scientists identified a shortlist, a kind of "periodic table" of the most designable knot types, i.e. those knots that could easily self-assemble under appropriate physical and chemical conditions. The findings, obtained with computational predictive models, are supported by the latest experimental results and ought to aid the synthesis of as yet undiscovered topologies. This study, and the increasingly predictive capability of molecular modeling techniques, can create novel possibilities for future advanced applications, like the construction of sophisticated molecular machines for loading and delivering nanoscale cargo.

Not just an intellectual challenge

"There is a growing scientific interest in complex molecules. In this context, the possibility to design and synthesize novel types of molecular knots is particularly appealing," says Mattia Marenda, first author of this research.

"Until recently, only few types of molecular knots had been synthesized. These were the simplest knots in mathematic tables, i.e. those having at most 5 essential crossings." One could have thus predicted that the next knot type to be synthesized would have had six crossings. However, in a computational study of 2015, co-author Cristian Micheletti and collaborators argued that the simplest and most designable undiscovered knot type was significantly more complex and featured as many as eight essential crossings. This prediction was experimentally confirmed in 2017 and motivated the current study, which employed a more systematic exploration of the shapes or configurations that can be formed from identical building blocks stitched together in a string-like fashion.

"With these models, we aimed at discovering which new molecular knots types, if any, would be easiest to obtain with current synthetic chemistry techniques, particularly self-assembly. We found that these privileged knot types do exist, but are very rare. Only a dozen different topologies are realisable among millions of simple knot types. The results of our models had an inherent simplicity," says Marenda. "The molecular weaving of these knot types is modular and highly symmetric. We used these features as selection criteria to sift the huge combinatorial space of molecular weaving patterns and obtained a shortlist of knot types expected to be easily assembled from few identical building blocks."

"The shortlist is similar to a periodic table, in that it is organised in rows and columns which reflect different aspects of the expected difficulty of practical realization," continues Micheletti. "The results are supported by recent experiments and this suggests that the table could indeed be useful to experimental chemists for choosing the target topologies for further studies and applications."

What are possible long-term results of this research? "At this time," explains Marenda, "chemists and physicists have mostly focused on proof-of-concept demonstrations of the design and synthesis of molecular knots. Nonetheless, interesting applicative avenues have already been suggested."

A chief example is the assembly of molecular cages: "In this case, specific substances could be nested or trapped within weavings of synthetic molecular knots. The latter could then serve as a controllable molecular machine, capable of loading or releasing a nanoscale cargo depending on the specific physico-chemical conditions. These are interesting and appealing perspectives for possible applications in medicine or electronics." [16]

In a first, scientists precisely measure how synthetic diamonds grow

Natural diamond is forged by tremendous pressures and temperatures deep underground. But synthetic diamond can be grown by nucleation, where tiny bits of diamond "seed" the growth of bigger diamond crystals. The same thing happens in clouds, where particles seed the growth of ice crystals that then melt into raindrops.

Scientists have now observed for the first time how diamonds grow from seed at an atomic level, and discovered just how big the seeds need to be to kick the crystal growing process into overdrive.

The results, published this week in *Proceedings of the National Academy of Sciences*, shed light on how nucleation proceeds not just in diamonds, but in the atmosphere, in silicon crystals used for computer chips and even in proteins that clump together in neurological diseases.

"Nucleation growth is a core tenet of materials science, and there's a theory and a formula that describes how this happens in every textbook," says Nicholas Melosh, a professor at Stanford University and the Department of Energy's SLAC National Accelerator Laboratory who led the research. "It's how we describe going from one material phase to another, for example from liquid water to ice."

But interestingly, he says, "despite the widespread use of this process everywhere, the theory behind it had never been tested experimentally, because observing how crystal growth starts from atomic-scale seeds is extremely difficult."

The smallest possible specks

In fact, scientists have known for a long time that the current theory often overestimates how much energy it takes to kick off the nucleation process, and by quite a bit. They've come up with potential ways to reconcile the theory with reality, but until now those ideas have been tested only at a relatively large scale, for instance with protein molecules, rather than at the atomic scale where nucleation begins.

To see how it works at the smallest scale, Melosh and his team turned to diamondoids, the tiniest possible bits of diamond. The smallest ones contain just 10 carbon atoms. These specks are the focus of a DOE-funded program at SLAC and Stanford where naturally occurring diamondoids are isolated from petroleum fluids, sorted by size and shape and studied. Recent experiments suggest they could be used as Lego-like blocks for assembling nanowires or "molecular anvils" for triggering chemical reactions, among other things.

The latest round of experiments was led by Stanford postdoctoral researcher Matthew Gebbie. He's interested in the chemistry of interfaces – places where one phase of matter encounters another, for instance the boundary between air and water. It turns out that interfaces are incredibly important in growing diamonds with a process called CVD, or chemical vapor deposition, that's widely used to make synthetic diamond for industry and jewelry.

"What I'm excited about is understanding how size and shape and molecular structure influence the properties of materials that are important for emerging technologies," Gebbie says. "That includes nanoscale diamonds for use in sensors and in quantum computing. We need to make them reliably and with consistently high quality."

Diamond or pencil lead?

To grow diamond in the lab with CVD, tiny bits of crushed diamond are seeded onto a surface and exposed to a plasma – a cloud of gas heated to such high temperatures that electrons are stripped away from their atoms. The plasma contains hydrogen and carbon, the two elements needed to form a diamond.

This plasma can either dissolve the seeds or make them grow, Gebbie says, and the competition between the two determines whether bigger crystals form. Since there are many ways to pack carbon atoms into a solid, it all has to be done under just the right conditions; otherwise you can end up with graphite, commonly known as pencil lead, instead of the sparkly stuff you were after.

Diamondoid seeds give scientists a much finer level of control over this process. Although they're too small to see directly, even with the most powerful microscopes, they can be precisely sorted according to the number of carbon atoms they contain and then chemically attached to the surface of a silicon wafer so they're pinned in place while being exposed to plasma. The crystals that grow around the seeds eventually get big enough to count under a microscope, and that's what the researchers did.

The magic number is 26

Although diamondoids had been used to seed the growth of diamonds before, these were the first experiments to test the effects of using seeds of various sizes. The team discovered that crystal growth really took off with seeds that contain at least 26 carbon atoms.

Even more important, Gebbie says, they were able to directly measure the energy barrier that diamondoid particles have to overcome in order to grow into crystals.

"It was thought that this barrier must be like a gigantic mountain that the carbon atoms should not be able to cross – and, in fact, for decades there's been an open question of why we could even make diamonds in the first place," he says. "What we found was more like a mild hill."

Gebbie adds, "This is really fundamental research, but at the end of the day, what we're really excited about and driving for is a predictable and reliable way to make diamond nanomaterials. Now that we've developed the underlying scientific knowledge needed to do that, we'll be looking for ways to put these diamond nanomaterials to practical use." [15]

Tunable diamond string may hold key to quantum memory

A quantum internet promises completely secure communication. But using quantum bits or qubits to carry information requires a radically new piece of hardware—a quantum memory. This atomic-scale device needs to store quantum information and convert it into light to transmit across the network.

A major challenge to this vision is that qubits are extremely sensitive to their environment, even the vibrations of nearby atoms can disrupt their ability to remember information. So far, researchers have relied on extremely low temperatures to quiet vibrations but, achieving those temperatures for large-scale quantum networks is prohibitively expensive.

Now, researchers at the Harvard John A. Paulson School of Engineering and Applied Sciences (SEAS) and the University of Cambridge have developed a quantum memory solution that is as simple as tuning a guitar.

The researchers engineered diamond strings that can be tuned to quiet a qubit's environment and improve memory from tens to several hundred nanoseconds, enough time to do many operations on a quantum chip.

"Impurities in diamond have emerged as promising nodes for quantum networks," said Marko Loncar, the Tiantsai Lin Professor of Electrical Engineering at SEAS and senior author of the research. "However, they are not perfect. Some kinds of impurities are really good at retaining information but have a hard time communicating, while others are really good communicators but suffer from memory loss. In this work, we took the latter kind and improved the memory by ten times."

The research is published in *Nature Communications*.

Impurities in diamond, known as silicon-vacancy color centers, are powerful qubits. An electron trapped in the center acts as a memory bit and can emit single photons of red light, which would in turn act as long-distance information carriers of a quantum internet. But with the nearby atoms in the diamond crystal vibrating randomly, the electron in the center quickly forgets any quantum information it is asked to remember.

"Being an electron in a color center is like trying to study at a loud marketplace," said Srujan Meesala, a graduate student at SEAS and co-first author of the paper. "There is all this noise around you. If you want to remember anything, you need to either ask the crowds to stay quiet or find a way to focus over the noise. We did the latter."

To improve memory in a noisy environment, the researchers carved the diamond crystal housing the color center into a thin string, about one micron wide—a hundred times thinner than a strand of hair—and attached electrodes to either side. By applying a voltage, the diamond string stretches and increases the frequency of vibrations the electron is sensitive to, just like tightening a guitar string increases the frequency or pitch of the string.

"By creating tension in the string, we increase the energy scale of vibrations that the electron is sensitive to, meaning it can now only feel very high energy vibrations," said Meesala. "This process effectively turns the surrounding vibrations in the crystal to an irrelevant background hum, allowing the electron inside the vacancy to comfortably hold information for hundreds of nanoseconds, which can be a really long time on the quantum scale. A symphony of these tunable diamond strings could serve as the backbone of a future quantum internet."

Next, the researchers hope to extend the memory of the qubits to the millisecond, which would enable hundreds of thousands of operations and long-distance quantum communication. [14]

Intel unveils 49-qubit superconducting chip

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

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

Large-scale integration

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

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

Commercial quest

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

Scientists explore quantum properties in the two-dimensional limit

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

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

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

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

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

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

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

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

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

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

Entanglement is an inevitable feature of reality

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

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

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

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

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

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

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

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

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

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

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

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

Ronald Hanson, Delft University of Technology, Netherlands

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

Anton Zeilinger, University of Vienna, Austria

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

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

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

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

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

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

How to Win at Bridge Using Quantum Physics

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

Quantum Information

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

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

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

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

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

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

Quantum Teleportation

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

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

Quantum Computing

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

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

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

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

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

Quantum Entanglement

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

The Bridge

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

Accelerating charges

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

Relativistic effect

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

Heisenberg Uncertainty Relation

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

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

Wave – Particle Duality

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

Atomic model

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

The Relativistic Bridge

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

The weak interaction

The weak interaction transforms an electric charge in the diffraction pattern from one side to the other side, causing an electric dipole momentum change, which violates the CP and time reversal symmetry. The Electroweak Interaction shows that the Weak Interaction is basically electromagnetic in nature. The arrow of time shows the entropy grows by changing the temperature dependent diffraction patterns of the electromagnetic oscillators.

Another important issue of the quark model is when one quark changes its flavor such that a linear oscillation transforms into plane oscillation or vice versa, changing the charge value with 1 or -1. This kind of change in the oscillation mode requires not only parity change, but also charge and time changes (CPT symmetry) resulting a right handed anti-neutrino or a left handed neutrino.

The right handed anti-neutrino and the left handed neutrino exist only because changing back the quark flavor could happen only in reverse, because they are different geometrical constructions, the u is 2 dimensional and positively charged and the d is 1 dimensional and negatively charged. It needs also a time reversal, because anti particle (anti neutrino) is involved.

The neutrino is a 1/2spin creator particle to make equal the spins of the weak interaction, for example neutron decay to 2 fermions, every particle is fermions with ½ spin. The weak interaction changes the entropy since more or less particles will give more or less freedom of movement. The entropy change is a result of temperature change and breaks the equality of oscillator diffraction intensity of the Maxwell–Boltzmann statistics. This way it changes the time coordinate measure and makes possible a different time dilation as of the special relativity.

The limit of the velocity of particles as the speed of light appropriate only for electrical charged particles, since the accelerated charges are self maintaining locally the accelerating electric force. The neutrinos are CP symmetry breaking particles compensated by time in the CPT symmetry, that is the time coordinate not works as in the electromagnetic interactions, consequently the speed of neutrinos is not limited by the speed of light.

The weak interaction T-asymmetry is in conjunction with the T-asymmetry of the second law of thermodynamics, meaning that locally lowering entropy (on extremely high temperature) causes the weak interaction, for example the Hydrogen fusion.

Probably because it is a spin creating movement changing linear oscillation to 2 dimensional oscillation by changing d to u quark and creating anti neutrino going back in time relative to the proton and electron created from the neutron, it seems that the anti neutrino fastest then the velocity of the photons created also in this weak interaction?

A quark flavor changing shows that it is a reflection changes movement and the CP- and T-symmetry breaking!!! This flavor changing oscillation could prove that it could be also on higher level such as atoms, molecules, probably big biological significant molecules and responsible on the aging of the life.

Important to mention that the weak interaction is always contains particles and antiparticles, where the neutrinos (antineutrinos) present the opposite side. It means by Feynman's interpretation that these particles present the backward time and probably because this they seem to move faster than the speed of light in the reference frame of the other side.

Finally since the weak interaction is an electric dipole change with ½ spin creating; it is limited by the velocity of the electromagnetic wave, so the neutrino's velocity cannot exceed the velocity of light.

The General Weak Interaction

The Weak Interactions T-asymmetry is in conjunction with the T-asymmetry of the Second Law of Thermodynamics, meaning that locally lowering entropy (on extremely high temperature) causes

for example the Hydrogen fusion. The arrow of time by the Second Law of Thermodynamics shows the increasing entropy and decreasing information by the Weak Interaction, changing the temperature dependent diffraction patterns. A good example of this is the neutron decay, creating more particles with less known information about them.
The neutrino oscillation of the Weak Interaction shows that it is a general electric dipole change and it is possible to any other temperature dependent entropy and information changing diffraction pattern of atoms, molecules and even complicated biological living structures.
We can generalize the weak interaction on all of the decaying matter constructions, even on the biological too. This gives the limited lifetime for the biological constructions also by the arrow of time. There should be a new research space of the Quantum Information Science the 'general neutrino oscillation' for the greater then subatomic matter structures as an electric dipole change.

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

Fermions and Bosons

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

Van Der Waals force

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

Electromagnetic inertia and mass

Electromagnetic Induction

Since the magnetic induction creates a negative electric field as a result of the changing acceleration, it works as an electromagnetic inertia, causing an electromagnetic mass. [1]

Relativistic change of mass

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

The frequency dependence of mass

Since $E = h\nu$ and $E = mc^2$, $m = h\nu / c^2$ that is the m depends only on the ν frequency. It means that the mass of the proton and electron are electromagnetic and the result of the electromagnetic induction, caused by the changing acceleration of the spinning and moving charge! It could be that the m_o inertial mass is the result of the spin, since this is the only accelerating motion of the electric charge. Since the accelerating motion has different frequency for the electron in the atom and the proton, they masses are different, also as the wavelengths on both sides of the diffraction pattern, giving equal intensity of radiation.

Electron – Proton mass rate

The Planck distribution law explains the different frequencies of the proton and electron, giving equal intensity to different lambda wavelengths! Also since the particles are diffraction patterns they have some closeness to each other – can be seen as a gravitational force. [2]

There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a high probability event. The asymmetric sides are creating different frequencies of electromagnetic radiations being in the same intensity level and compensating each other. One of these compensating ratios is the electron – proton mass ratio. The lower energy side has no compensating intensity level, it is the dark energy and the corresponding matter is the dark matter.

Gravity from the point of view of quantum physics

The Gravitational force

The gravitational attractive force is basically a magnetic force.

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

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

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

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

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

The gravitational force attracting the matter, causing concentration of the matter in a small space and leaving much space with low matter concentration: dark matter and energy.
There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a high probability event. The asymmetric sides are creating different frequencies of electromagnetic radiations being in the same intensity level and compensating each other. One of these compensating ratios is the electron – proton mass ratio. The lower energy side has no compensating intensity level, it is the dark energy and the corresponding matter is the dark matter.

The Higgs boson

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

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

Higgs mechanism and Quantum Gravity

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

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

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

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

What is the Spin?

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

The Graviton

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

Conclusions

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

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

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

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

The key breakthrough to arrive at this new idea to build qubits was to exploit the ability to control the nuclear spin of each atom. With that insight, the team has now conceived a unique way to use the nuclei as facilitators for the quantum logic operation between the electrons. [5]

Basing the gravitational force on the accelerating Universe caused magnetic force and the Planck Distribution Law of the electromagnetic waves caused diffraction gives us the basis to build a Unified Theory of the physical interactions also.

References

[1] The Magnetic field of the Electric current and the Magnetic induction

http://academia.edu/3833335/The_Magnetic_field_of_the_Electric_current

[2] 3 Dimensional String Theory

http://academia.edu/3834454/3_Dimensional_String_Theory [3] Graviton Production By Two Photon and Electron-Photon Processes In Kaluza-Klein Theories With Large Extra Dimensions

http://arxiv.org/abs/hep-ph/9909392 [4] Quantum Entanglement

http://en.wikipedia.org/wiki/Quantum_entanglement [5] Pairing up single atoms in silicon for quantum computing http://phys.org/news/2014-06-pairing-atoms-silicon-quantum.html#nwlt

[6] How to Win at Bridge Using Quantum Physics http://www.wired.com/2014/06/bridge-quantum-mechanics/

[7] Information Entropy-Theory of Physics https://www.academia.edu/3836084/Information_-_Entropy_Theory_of_Physics

[8] Quantum Teleportation http://en.wikipedia.org/wiki/Quantum_teleportation

[9] Bell Prize goes to scientists who proved 'spooky' quantum entanglement is real https://phys.org/news/2017-08-bell-prize-scientists-spooky-quantum.html

[10] Entanglement is an inevitable feature of reality https://phys.org/news/2017-09-entanglement-inevitable-feature-reality.html

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

http://trendintech.com/2017/09/04/do-physicists-need-to-change-the-way-they-measurequantum-states/

[12] Scientists explore quantum properties in the two-dimensional limit

https://phys.org/news/2017-12-scientists-explore-quantum-properties-two-dimensional.html

[13] Intel unveils 49-qubit superconducting chip

https://physicsworld.com/a/intel-unveils-49-qubit-superconducting-chip/

[14] Tunable diamond string may hold key to quantum memory

https://phys.org/news/2018-05-tunable-diamond-key-quantum-memory.html

[15] In a first, scientists precisely measure how synthetic diamonds grow

https://phys.org/news/2018-08-scientists-precisely-synthetic-diamonds.html

[16] A periodic table of molecular knots

https://phys.org/news/2018-08-periodic-table-molecular.html

[17] When mixing granular matter, order among disorder

https://phys.org/news/2018-08-granular-disorder.html

[18] Order hidden in disorder

https://phys.org/news/2019-04-hidden-disorder.html