Spot Anyons

Well-established spectroscopic techniques such as neutron scattering could be used to identify anyons in two-dimensional materials. [17]

Now in a new paper published in Physical Review Letters, mathematical physicist Paul Sutcliffe at Durham University in the UK has theoretically shown that nanoparticles called magnetic skyrmions can be tied into various types of knots with different magnetic properties. [16]

A new study by researchers at the U.S. Department of Energy's Argonne National Laboratory determined that magnetic skyrmions – small electrically uncharged circular structures with a spiraling magnetic pattern – do get deflected by an applied current, much like a curveball getting deflected by air. [15]

Researchers at Aalto University and Lawrence Berkeley National Laboratory have demonstrated that polaron formation also occurs in a system of magnetic charges, and not just in a system of electric charges. Being able to control the transport properties of such charges could enable new devices based on magnetic rather than electric charges, for example computer memories. [14]

The electronic energy states allowed by quantum mechanics determine whether a solid is an insulator or whether it conducts electric current as a metal. Researchers at ETH have now theoretically predicted a novel material whose energy states exhibit a hitherto unknown peculiarity. [13]

Quantum magnetism, in which – unlike magnetism in macroscopic-scale materials, where electron spin orientation is random – atomic spins self-organize into one-dimensional rows that can be simulated using cold atoms trapped along a physical structure that guides optical spectrum electromagnetic waves known as a photonic crystal waveguide. [12]

Scientists have achieved the ultimate speed limit of the control of spins in a solid state magnetic material. The rise of the digital information era posed a daunting challenge to develop ever faster and smaller devices for data storage and processing. An approach which relies on the magnetic moment of electrons (i.e. the spin) rather than the charge, has recently turned into major research fields, called spintronics and magnonics. [11]

A team of researchers with members from Germany, the U.S. and Russia has found a way to measure the time it takes for an electron in an atom to respond to a pulse of light. [10]

As an elementary particle, the electron cannot be broken down into smaller particles, at least as far as is currently known. However, in a phenomenon called electron fractionalization, in certain materials an electron can be broken down into smaller "charge pulses," each of which carries a fraction of the electron's charge. Although electron fractionalization has many interesting implications, its origins are not well understood. [9]

New ideas for interactions and particles: This paper examines the possibility to origin the Spontaneously Broken Symmetries from the Planck Distribution Law. This way we get a Unification of the Strong, Electromagnetic, and Weak Interactions from the interference occurrences of oscillators. Understanding that the relativistic mass change is the result of the magnetic induction we arrive to the conclusion that the Gravitational Force is also based on the electromagnetic forces, getting a Unified Relativistic Quantum Theory of all 4 Interactions.

Author: George Rajna

Synopsis: How to Spot Anyons

Quantum particles are either fermions or bosons, if they live in three dimensions. Confine them in two dimensions, and they can also be anything between the two types of particle—what Frank Wilczek at the Massachusetts Institute of Technology, Cambridge, dubbed an anyon. While they are relatively simple to describe theoretically, anyons remain hard to spot in experiments. Now a quartet of researchers, including Wilczek himself, says that well-established spectroscopic techniques could provide a simple means to identify anyons. The proposal could help experimentalists discover systems that can host non-Abelian anyons, a class of anyons that is expected to be useful for fault-tolerant quantum computing.

To identify anyons in a material, researchers look for signatures of the particles' peculiar quantum statistics, which lie between the Fermi-Dirac statistics of fermions and the Bose-Einstein statistics of bosons. They usually do this with particle interferometry and entropy measurements. Both of these measurements, however, are difficult to perform: the interference of anyons is hard to isolate, and the entropies associated with the particles are tiny. Wilczek and colleagues demonstrate that well-established spectroscopic techniques such as neutron scattering could do the job. For neutron scattering, for example, they derive the probability that a neutron of certain energy will produce anyons when it hits a material. They find that, at energies close to the threshold for producing the anyons, the probability contains a clear signature of the particles. Specifically, it follows a power law with an exponent whose value depends on where exactly the anyonic statistics lie between the fermionic and bosonic types. [17]

Magnetic nanoknots evoke Lord Kelvin's vortex theory of atoms

In the late 1800s when scientists were still trying to figure out what exactly atoms are, one of the leading theories, proposed by Lord Kelvin, was that atoms are knots of swirling vortices in the aether. Although this idea turned out to be completely wrong, it ushered in modern knot theory, which today is used in various areas of science such as fluid dynamics, the structure of DNA, and the concept of chirality.

Now in a new paper published in Physical Review Letters, mathematical physicist Paul Sutcliffe at Durham University in the UK has theoretically shown that nanoparticles called magnetic skyrmions can be tied into various types of knots with different magnetic properties. He explains that, in a sense, these nanoknots represent a "nanoscale resurrection of Kelvin's dream of knotted fields."

Skyrmions are the name of a general class of particles that are made by twisting a field. When this field is a magnetic field, the skyrmions are called magnetic skyrmions. Magnetic skyrmions have attracted a lot of attention recently due to their potential applications in spintronics, where electron spins (which are related to the electron's magnetic properties) are exploited in the design of transistors, storage media, and related devices.

Magnetic skyrmions were experimentally observed for the first time a few years ago, in thin slices of magnetic materials—basically two-dimensional materials. By showing that magnetic skyrmions can theoretically be tied into knots, the new results move these particles from the two-dimensional world to the three-dimensional one.

"The most significant point is that these nanoknots are stable, because usually fields avoid being knotted by untying themselves," Sutcliffe told Phys.org.

Sutcliffe showed that the skyrmion knots can be characterized by the Hopf charge, which indicates the number of times that a skyrmion's curved magnetic lines are linked with each other. He showed that skyrmions with low Hopf charges tend to form rings, while those with higher Hopf charges form links and knots.

Sutcliffe's investigation focuses on magnetic skyrmions in a particular type of magnet called frustrated magnets, which offer skyrmions an additional rotational degree of freedom compared to other magnetic materials. This flexibility gives skyrmions the extra room needed to be tied into knots.

At the time Sutcliffe was writing his paper, no one had ever observed skyrmions in frustrated magnets. But as a testament to the fast pace of research in this area, just a few days after this publication researchers from China reported the first experimental observations of skyrmions in a frustrated magnet (arXiv:1706.05177 [cond-mat.mtrl-sci]).

This result marks an important step toward realizing knotted magnetic skyrmions, and the next challenge will be to find a way to engineer the skyrmions into knots. Recent work on skyrmions has suggested that these particles may be controlled using optical vortex beams, arrays of ferromagnetic nanorods, and other methods. Researchers are also currently developing imaging techniques for skyrmions, which will be essential for the identification of these nanoknots. With new results on skyrmions being reported almost daily, Sutcliffe is optimistic about the prospects of creating skyrmion knots.

"My future research plans in this area are concerned with studying the formation of these nanoknots, to help develop methods and suggest favorable conditions for experimentalists to create and observe these structures," Sutcliffe said. [16]

Team ahead of the 'curve' in magnetic study

A new study by researchers at the U.S. Department of Energy's Argonne National Laboratory determined that magnetic skyrmions – small electrically uncharged circular structures with a spiraling magnetic pattern – do get deflected by an applied current, much like a curveball getting deflected by air.

When a baseball pitcher uncorks a nasty curveball, the spinning motion of the ball forces air to flow around it at different speeds, causing the ball to "break" in one direction.

The physics behind this kind of deflection also work at smaller scales. For certain physical systems at the atomic level, a similar phenomenon occurs. Scientists have known for years that electrons get deflected when a magnetic field is applied.

However, until now scientists did not have a way of seeing if and how certain non-electrically charged, but magnetically organized, structures also take a curved path under an applied current—and the answer to that question could have big implications in the world of data storage.

In a new study by researchers at the U.S. Department of Energy's (DOE's) Argonne National Laboratory, scientists noticed that magnetic skyrmions – small electrically uncharged circular structures with a spiraling magnetic pattern—do get deflected by an applied current. Although skyrmions do not have electric charge, they do have what researchers call "topological charge," and it is this charge that causes their deflection.

"We noticed that the angle of deflection is dependent on the size of the skyrmion and the amount of current that we apply," said Argonne physicist Suzanne te Velthuis, who led the study.

Being able to manipulate the motion of skyrmions is of interest to materials scientists because the magnetic textures of the structures could serve as a method to encode data with low power. With the ability to control the motion of skyrmions with a small current, researchers could manipulate them in memory devices that form the basis of a new regime known as spintronics.

The researchers also noticed that the motion of the skyrmions caused by the applied current could be affected by defects or by how close the skyrmions come to the edge of the material.

"You can also think of the skyrmion motion as like trying to roll a bowling ball across a bowling alley," said Argonne materials scientist Axel Hoffmann, another author of the study. "If the alley is smooth, the ball or skyrmion will roll one way, but if it has many divots like an egg carton, it will roll very differently."

Sometimes if a skyrmion reaches the edge of the material, it will bounce back; in other cases, however, the skyrmion will disappear once it reaches the edge. "If we want to be able to use skyrmions for data encoding, we want to make sure that we do not lose the information that is embedded in the skyrmion," said former Argonne postdoctoral researcher Wanjun Jiang, the first author of the study.

"Understanding skyrmion physics could open up a wide range of new devices that are as yet still hypothetical," said Bryn Mawr College graduate student Xiao Wang, another author of the study.

A paper based on the study, "Direct Observation of the Skyrmion Hall Effect," appeared in the September 19 issue of Nature Physics. [15]

Magnetic polaron imaged for the first time

Researchers at Aalto University and Lawrence Berkeley National Laboratory have demonstrated that polaron formation also occurs in a system of magnetic charges, and not just in a system of electric charges. Being able to control the transport properties of such charges could enable new devices based on magnetic rather than electric charges, for example computer memories. Polarons are an example of emergent phenomena known to occur in condensed matter physics. For instance, an electron moving across a crystal lattice displaces the surrounding ions, together creating an effective quasi-particle, a polaron, which has an energy and mass that differs from that of a bare electron. Polarons have a profound effect on electronic transport in materials.

Artificial spin ice systems are metamaterials that consist of lithographically patterned nanomagnets in an ordered two-dimensional geometry. The individual magnetic building blocks of a spin ice lattice interact with each other via dipolar magnetic fields.

Researchers used material design as a tool to create a new artificial spin ice, the dipolar dice lattice.

'Designing the correct two-dimensional lattice geometry made it possible to create and observe the decay of magnetic polarons in real-time,' says postdoctoral researcher Alan Farhan from Lawrence Berkeley National Laboratory (USA).

'We introduced the dipolar dice lattice because it offers a high degree of frustration, meaning that competing magnetic interactions cannot be satisfied simultaneously. Like all systems in nature, the dipolar dice lattice aims to relax and settle into a low-energy state. As a result, whenever magnetic charge excitations emerge over time, they tend to get screened by opposite magnetic charges from the environment,' explains Dr. Farhan.

The researchers at Berkeley used photoemission electron microscopy, or PEEM, to make the observations. This technique images the direction of magnetization in individual nanomagnets. With the magnetic moments thermally fluctuating, the creation and decay of magnetic polarons could be imaged in real space and time.

Postdoctoral researcher Charlotte Peterson and Professor Mikko Alava at Aalto University (Finland) performed simulations, which confirmed the rich thermodynamic behavior of the spin ice system.

'The experiments also demonstrate that magnetic excitations can be engineered at will by a clever choice of lattice geometry and the size and shape of individual nanomagnets. Thus, artificial spin ice is a prime example of a designer material. Instead of accepting what nature offers, it is now possible to assemble new materials from known building blocks with purposefully designed functionalities,' says Professor Sebastiaan van Dijken from Aalto University.

'This concept, which goes well beyond magnetic metamaterials, is only just emerging and will dramatically shape the frontier of materials research in the next decade,' adds Professor van Dijken. [14]

Metal in chains

The electronic energy states allowed by quantum mechanics determine whether a solid is an insulator or whether it conducts electric current as a metal.

Researchers at ETH have now theoretically predicted a novel material whose energy states exhibit a hitherto unknown peculiarity.

If one looked deep into three different solids using a super-microscope, one would, in principle, always see the same thing: atomic nuclei arranged in a crystal lattice and electrons, of which some orbit the atomic nuclei and others criss-cross the entire crystal lattice. Nevertheless, those three materials might behave very differently when an electric voltage is applied to them.

The first solid might, for instance, conduct an electric current, the second one might turn out to be an insulator, and the third one could be a semiconductor - that is, a material whose electric conductivity increases with increasing temperature (rather than diminishing, which is the case for metals) and that is the basis for transistors and computer chips.

A team of physicists led by Manfred Sigrist, Alexey Soluyanov and Andreas Rüegg at the Institute for Theoretical Physics of the ETH in Zurich have now predicted a new kind of solid they call "nodal chain metal" that is expected to have hitherto unknown properties. Moreover, they have already identified a potential candidate among existing materials.

Band structure and Fermi level

Two quantities determine, by and large, if and how a solid conducts electric current: its band structure and its Fermi level. The band structure refers to the possible energy states the electrons inside it can occupy. Whereas a free electron accumulates kinetic energy as it moves faster and faster, electrons embedded in a crystal lattice can only take on energy values that lie inside certain intervals or "bands".

This follows from their quantum mechanical wave nature, which is also responsible for the fact that some values of the motional energy are off limits for electrons; those are also called band gaps. The Fermi level, on the other hand, derives from the fermionic nature of electrons, which means that two of them can never occupy the same energy state. If one were to build up a solid one particle at a time, each newly added electron would try to occupy higher and higher energy levels, starting from zero energy. The energy of the last electron would then be the Fermi level.

Whether a material is a metal or an insulator can now be easily predicted if its energy bands and its Fermi level are known. If the Fermi level lies inside a band, the most energetic electrons can move easily and hence conduct electric current. If, on the other hand, the Fermi level coincides with a band gap, one has an insulator. By the same token, other materials may be metals by that definition, but with very few possible energy states at the Fermi level. "The material we predict is, if you will, a cousin of such so-called semimetals", explains Tomàš Bzdušek, a PhD student with Sigrist and Rüegg.

Nodes in the semimetal

One semimetal that has made the headlines is graphene. The particular way in which the energy bands of graphene's electrons approach each other at so-called Dirac points is responsible for the electrical and thermal conductivities of this peculiar material, whose discoverers were awarded the Nobel Prize in Physics in 2010. Since the band gap actually vanishes at the Dirac points, they are also called nodes (in analogy with the nodes of a standing wave).

In other semimetals the energy bands touch not at isolated points but along well-defined lines or surfaces. "The peculiarity of our new material is that its energy bands touch along interconnected nodal loops, and those nodal loops form a chain", says Soluyanov. "That may sound strange and rather theoretical, but we have actually found a real material that is likely to have those properties. That such nodal chains should appear is not an accident, but dictated by the symmetries of the material's crystal lattice."

Incidentally, physicists are able to draw an interesting analogy between solid state and high energy particle physics. In high-energy theories nodal chains would be impossible due to the high level of symmetry of the vacuum. In a crystal, by contrast, there are far fewer symmetries, creating a kind of novel vacuum.

To find the nodal chain material the researchers took a long and winding road. Assuming it would be easier, they first set out to look for materials with a single nodal loop and determined what kind of symmetry properties the crystal lattice of such a material should have. All in all, 230 different types of crystal symmetries are known, and it is those symmetries that are largely responsible for the properties of a material's band structure.

Soluyanov and his colleagues then scoured massive online databases (ICSD - Inorganic Crystal Structure Database) in which thousands of known solids are listed alongside their crystal structures. Eventually, they chanced upon one that had not only a nodal loop, but the more intricate nodal chain: iridium tetrafluoride. "It was an unexpected surprise", admits Quan Sheng Wu, a member of the ETH team.

A possible prototype

This little known and, so far, not particularly useful solid could be the prototype for a new kind of material with potentially technologically interesting properties. For instance, the physicists in Zurich predict that the electric conductivity of such solids should be influenced by magnetic fields in a characteristic way. This phenomenon is also known as magneto-resistance and plays an important role in modern data storage technologies.

Furthermore, the band structure of iridium tetrafluoride has certain peculiarities that have been connected with higher-temperature superconductivity. "All of that's a long shot, of course", Sigrist concedes. Experimental tests of the novel nodal chain metals have still to be done, and surprises are quite possible. [13]

Simulated quantum magnetism can control spin interactions at arbitrary distances

Quantum magnetism, in which – unlike magnetism in macroscopic-scale materials, where electron spin orientation is random – atomic spins self-organize into one-dimensional rows that can be simulated using cold atoms trapped along a physical structure that guides optical spectrum electromagnetic waves known as a photonic crystal waveguide. Recently, scientists at Purdue University, Max-Planck-Institut für Quantenoptik, Germany, and California Institute of Technology, used this approach to devise a scheme for simulating quantum magnetism that provides full control of interactions between pairs of spins at arbitrary distances in 1D and 2D lattices, and moreover demonstrated the scheme's wide utility by generating several well-known spin models. The researchers state that their results allow the introduction of geometric phases into the spin system that could generate topological models with long-range spin–spin interactions.

Dr. Chen-Lung Hung, Dr. Alejandro González-Tudela and Phys.org discussed the study, its challenges and the resulting paper that they have published with their colleagues in Proceedings of the National Academy of Sciences. These challenges included using a two-photon Raman addressing scheme to devise their proposed atom-nanophotonic system – a system that can achieve arbitrary and dynamic control on the strength, phase, and length scale of spin interactions, as well as simulate quantum magnetism with full control of interactions between pairs of spins at arbitrary distances in 1D and 2D lattices. Moreover, the researchers showed that it is possible to introduce geometric phases into the spin system – and thereby realizing topological models with long-range spin–spin interactions – by carefully arranging the propagation phases of Raman beams.

"Cold atoms are an ideal system for studying quantum many-body problems due to their high degree of controllability and reproducibility," González-Tudela and Hung tell Phys.org. "To study various lattice spin models, state-of-the-art experiments load cold atoms into the so-called optical lattices, formed by interfering laser beams in free space. Despite past experimental successes in realizing, for example, superfluid-Mott insulator quantum phase transitions with cold atoms in optical lattices, there are, however, several limitations that preclude cold atoms from emulating a large class of many-body problems involving strong or long-range interactions." This is due to cold atoms being neutral systems that interact very weakly via contact potentials, González-Tudela explains, adding that this small interaction strength makes it difficult to study, for example, important quantum magnetism problems, since these require interactions between atoms in, at least, the adjacent lattice sites. "Decoherence sources can kick in before these very small interaction effects manifest – and on the other hand, short-range interactions also limit the amount of entanglement in the system."

To overcome this challenge and to increase interaction strength, González-Tudela continues, the scientists recently proposed1 to interface cold atoms with structured dielectrics, which with suitable engineering allows increased interaction strengths and range by letting the atoms talk through guided photons in the structure. "However," he points out, "the spatial dependence of the interactions is fixed by the spatial profile of the photon modes and so does not allow for full control in the interactions. This is why, in this paper, we combine our current and previous ideas, employing external magnetic fields and external multi-frequency laser beams to achieve full controllability of spin-spin interactions." In short, these two extra ingredients allow the researchers to achieve not only full control of pair-wise interactions, but also to introduce space-dependent phases through sideband engineering in the control laser beams – and this improved control has important consequences:

The ability to simulate long-range interactions with spatial dependence at will, not just fixed by the photon profile in the material. This has important consequences in the static properties of models that cannot be otherwise investigated, but also in the study of thermalization of closed systems with long-range interactions.

The possibility of introducing space-dependent phases allows the engineering of models with non-trivial topology with long-range interactions, something that is very difficult to obtain in other platforms.

The prospect of modifying boundary conditions at will allow exploration of non-trivial geometries that may give rise to exotic quantum states.

One of the key findings reported in the paper was the new avenues promised by the proposed platform for engineering a large class of spin Hamiltonians, including those exhibiting topological order or frustrated long-range magnetism (in which the atoms whose spin states are giving rise to quantum magnetism cannot settle into a state that minimizes each interaction). "Because the interactions can be engineered at will, many spin model that require long-range spin-exchange or direct spin-spin interactions can be engineered. Frustration phenomena due to competition between long-range spin-exchange and spin-spin interactions can be studied with great details. Moreover, by carefully controlling the optical phases of the external addressing laser beams, we can imprint a quantum mechanical phase on spins that hop along a closed contour. This gives us an opportunity to engineer the so-called geometrical phases in the spin model, which is responsible of inducing topological quantum phases such as quantum Hall states in 2D electron gases.

Another interesting result was showing that atom-nanophotonic systems present appealing platforms to engineer many-body quantum matter by using low-dimensional photons to mediate interaction between distant atom pairs. "Nanophotonic structures provide us a way to engineer the transport property of what we call effectively low-dimensional photons – that is, photons confined in a quasi-2D plane or a 1D wire. When used in nanophotonics, these low-dimensional photons are excellent force- or information-carrying mobile particles that can mediate interactions between distant atom pairs."

Relatedly, the study found that the proposed platform potentially allows for conducting detailed studies on quantum dynamics of long-range, strongly interacting spin systems that are driven out-of-equilibrium. "Dynamic control of interaction strengths is another important feature in our system," Hung points out. "In our Raman control scheme, long-range interaction can be dynamically adjusted via tuning either the amplitude or sidebands in the external control laser beam. Therefore, it will be very easy for the proposed platform to prepare a quantum system out-of-equilibrium and study the subsequent quantum spin dynamics."

On a more encompassing level, the paper states that the scientists expect that their platform may bring novel opportunities to the study of quantum thermalization in long-range many-body systems, or for further understanding of information propagation in a long-range quantum network. Specifically, not only could their platform allow the researchers to study dynamics of a quantum system driven out-of-equilibrium, as mentioned above, but also to investigate how quantum dynamics depends on the range of interactions. "This would provide information on how correlation or entanglement between atomic spins can propagate throughout the spin system, and whether the resulting spin state can still be analyzed as a pure state, or, rather, if it becomes indistinguishable from a statistical mixture," Hung says.

This would therefore provide an opportunity to study quantum thermalization in long-range systems. "Moreover," he continues, "by arbitrary, pairwise engineering of spin-spin interactions, we could establish our model system as a 'miniature' long-range quantum network where atoms are viewed as quantum nodes interconnected via guided photons in the nanophotonic channels. Out-of-equilibrium studies in such systems could provide greater understanding of information propagation in a model quantum network."

Of significant importance to the future capabilities of quantum communications is the development of much more robust resistance to sudden decoherence than now exists. Phys.org therefore asked Hung if their scheme might be a factor in this effort. "Two conditions might lead to sudden decoherence between a pair of local quantum spins – namely, either through coupling to surrounding or distant spins via long-range interactions that we view as an environment, or through dissipative coupling to unwanted nanophotonic channels or to free space. There could be complex behaviors in the engineered spin system, so we may find new surprises."

The paper also discussed the possibility of engineering periodic boundary conditions, as explicitly shown in the 1D Haldane–Shastry model or in other global lattice topologies, by introducing long-range interactions between spins located at the boundaries of a finite system. "Long-range interaction allows us to connect distant spins located at the opposite end of the boundary in a finite system as well as to engineer the connectivity of a local spin to neighboring spins – thereby opening up ways to engineer the global topology of a lattice spin model."

A fascinating aspect of the study discussed in the paper was the possibility of creating previously-unavailable spin-lattice geometries, such as Möbius strip, torus, or lattice models with singular curvatures such as conic geometries that may lead to localized topological states with potential applications in quantum computations. "Boundary conditions and global lattice geometries can play an important role in lattice models exhibiting topological phases," Hung states. "In particular, topological properties manifest as spin transport at the boundaries or near special points with singular lattice curvatures – and these support topological excitations that are stable against local perturbations. Using the proposed platform, especially with arbitrary long-range interactions, we can engineer or even dynamically control the boundary conditions or lattice topologies that are unavailable in other experimental platforms such as cold atoms in optical lattices. This may open up new ways to engineer transport, localization, or even braiding operations of topological excitations," an abstract topological approach to determining quantum operations, "which may find significant applications in topological quantum computations."

In terms of their ongoing research, Hung tells Phys.org that the researchers had great initial successes in developing a prototype alligator photonic crystal2. "Our experimental groups at Caltech and Purdue University are currently developing new nanophotonic platforms with improved optical qualities and band structures that are capable of mediating stronger atom-photon interaction within a large array of trapped atoms to realize the proposed scheme. Another interesting avenue in atom-nanophotonic hybrid system," he continues, "is to use nanostructures and the resulting attractive vacuum forces to form nanoscale lattice potentials for cold atoms. The vacuum force-induced lattice potentials work just as optical lattices in free space for cold atoms, but the lattice spacing – as small as 50 nm – is much smaller than those of the optical lattices, which are limited by the wavelength of interfering lasers. Reduced lattice spacing leads to more than 100 times increased energy scale in the quantum lattice model, improving the low temperature limitation of cold atom experiments. In the long term," González-Tudela concludes, "the possibility of having a platform where long-range interactions can be controlled at will may also impact the simulation of quantum chemistry problems." [12]

Femtosecond Laser pulses push Spintronics and Magnonics to the limit

Scientists have achieved the ultimate speed limit of the control of spins in a solid state magnetic material. The rise of the digital information era posed a daunting challenge to develop ever faster and smaller devices for data storage and processing. An approach which relies on the magnetic moment of electrons (i.e. the spin) rather than the charge, has recently turned into major research fields, called spintronics and magnonics.

The researchers were able to induce spin oscillations of the intrinsically highest frequency by using femtosecond laser pulses (1 fs = 10-15 sec). Furthermore, they demonstrated a complete and arbitrary manipulation of the phase and the amplitude of these magnetic oscillations – also called magnons. The length-scale of these magnons is on the order of 1 nanometre.

These results pave the way to the unprecedented frequency range of 20 THz for magnetic recording devices, which can be employed also at the nanometer scale.

The practical implementation of other schemes of magnetic control, based on the use of electric currents, is hampered by a significant heating which requires cooling systems. It is thus important to underline that the concept in the current publication does not involve any heating. This makes the study appealing from the point of view of future applications. However, the possibility to monitor the evolution of a magnet on such short time- and length- scales simultaneously is a major breakthrough also in terms of fundamental science. A new regime, defined by Dr. Bossini as femto-nanomagnonics, has been disclosed. [11]

Superfast light pulses able to measure response time of electrons to light

A team of researchers with members from Germany, the U.S. and Russia has found a way to measure the time it takes for an electron in an atom to respond to a pulse of light. In their paper published in the journal Nature, the team describes their use of a light field synthesizer to create pulses of light so fast that they were able to reveal the time it took for electrons in an atom to respond when struck. Kyung Taec Kim with the Gwangju Institute of Science offers a News & Views piece on the work done by the team in the same journal issue, outlining their work and noting one issue that still needs to be addressed with such work.

As scientists have begun preparing for the day when photons will replace electrons in high speed computers, work is being done to better understand the link between the two. One important aspect of this is learning what happens when photons strike electrons that remain in their atom (rather than being knocked out of them), specifically, how long does it take them to respond.

To find this answer, the researchers used what has come to be known as a light-field synthesizer—it is a device that is able to produce pulses of light that are just half of a single wavelength long—something many had thought was impossible not too long ago. The pulses are of such short duration that they only last for the time it takes to travel that half wavelength, which in this case, was approximately 380 attoseconds.

The light-field synthesizer works by combining several pulses of light brought together but slightly out of phase, allowing for canceling and ultimately, a single very short pulse. In their experiments, the researchers fired their super-short pulses at krypton atoms held inside of a vacuum. In so doing, they found that it took the electrons 115 attoseconds to respond—the first such measurement of the response time of an electron to a visible light pulse.

The team plans to continue their work by looking at how electrons behave in other materials, and as Kim notes, finding a way to characterize both the amplitude and phase of radiation from atoms driven by a light field. [10]

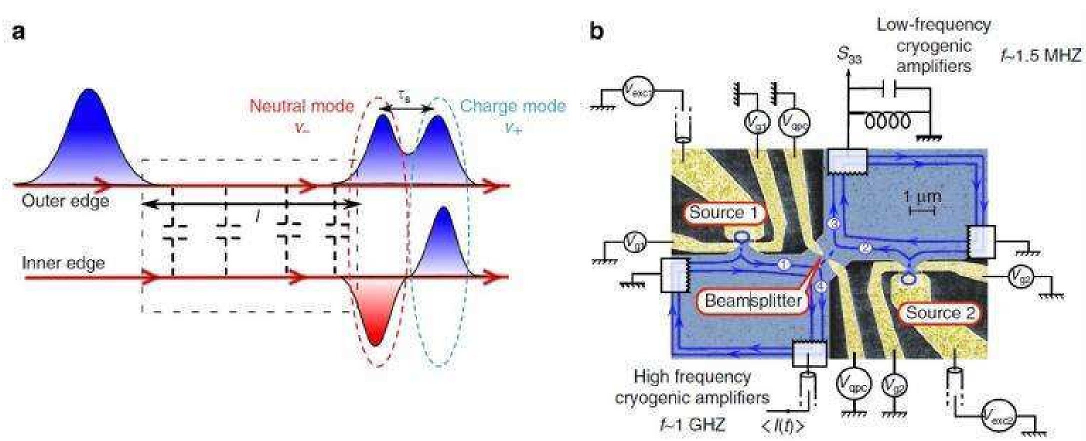
When an electron splits in two

Now in a new paper published in Nature Communications, a team of physicists led by Gwendal Fève at the Ecole Normale Supérieure in Paris and the Laboratory for Photonics and Nanostructures in Marcoussis have applied an experiment typically used to study photons to investigate the underlying mechanisms of electron fractionalization. The method allows the researchers to observe single-electron fractionalization on the picosecond scale.

"We have been able to visualize the splitting of an electronic wavepacket into two fractionalized packets carrying half of the original electron charge," Fève told Phys.org. "Electron fractionalization has been studied in previous works, mainly during roughly the last five years. Our work is the first to combine single-electron resolution—which allows us to address the fractionalization process at the elementary scale—with time resolution to directly visualize the fractionalization process."

The technique that the researchers used is called the Hong-Ou-Mandel experiment, which can be used to measure the degree of resemblance between two photons, or in this case electron charge pulses, in an interferometer. This experiment also requires a single-electron emitter, which some of the same researchers, along with many others, have recently been developing.

The researchers first analyzed the propagation of a single electron in the interferometer's outer one-dimensional wire, and then when that electron fractionalized, they could observe the interaction between its two charge pulses in the inner one-dimensional wire. As the researchers explain, when the original electron travels along the outer wire, Coulomb interactions (interactions between charged particles) between excitations in the outer and inner wires produce two types of excitation pairs: two pulses of the same sign (carrying a net charge) and two pulses of opposite signs (which together are neutral). The two different excitation pairs travel at different velocities, again due to Coulomb interactions, which causes the original electron to split into two distinct charge pulses.



(a) An electron on the outer channel fractionalizes into two pulses. (b) A modified scanning electron microscope picture of the sample. Credit: Freulon, et al. ©2015 Nature

The experiment reveals that, when a single electron fractionalizes into two pulses, the final state cannot be described as a single-particle state, but rather as a collective state composed of several excitations. For this reason, the fractionalization process destroys the original electron particle. Electron destruction can be measured by the decoherence of the electron's wave packet.

Gaining a better understanding of electron fractionalization could have a variety of implications for research in condensed matter physics, such as controlling single-electron currents in one-dimensional wires.

"There has been, during the past years, strong efforts to control and manipulate the propagation of electrons in electronic conductors," Fève said. "It bears many analogies with the manipulations of the quantum states of photons performed in optics. For such control, one-dimensional conductors are useful, as they offer the possibility to guide the electrons along a one-dimensional trajectory. However, Coulomb interactions between electrons are also very strong in one-dimensional wires, so strong that electrons are destroyed: they fractionalize. Understanding fractionalization is understanding the destruction mechanism of an elementary electron in a one-dimensional wire. Such understanding is very important if one wants to control electronic currents at the elementary scale of a single electron."

In the future, the researchers plan to perform further experiments with the Hong-Ou-Mandel interferometer in order to better understand why fractionalization leads to electron destruction, and possibly how to suppress fractionalization.

"The Hong-Ou-Mandel interferometer can be used to picture the temporal extension (or shape) of the electronic wavepackets, which is what we used to visualize the fractionalization process," Fève said. "It can also be used to capture the phase relationship (or phase coherence) between two components of the electronic wavepacket.

"This combined information fully defines the single-electron state, offering the possibility to visualize the wavefunction of single electrons propagating in a one-dimensional conductor. This would first provide a complete understanding of the fractionalization mechanism and in particular how it leads to the decoherence of single-electron states. It would also offer the possibility to test if single electrons can be protected from this decoherence induced by Coulomb interaction. Can we suppress (or reduce) the fractionalization process by reducing the strength of the Coulomb interaction? We would then be able to engineer and visualize pure single-electron states, preserved from Coulomb interaction.

"The next natural step is then to address few-particle states and electron entanglement in quantum conductors. Again, the question of the destruction of such states by Coulomb interaction effects will be a crucial one." [9]

The Electromagnetic Interaction

This paper explains the magnetic effect of the electric current from the observed effects of the accelerating electrons, causing naturally the experienced changes of the electric field potential along the electric wire. 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. [2]

Asymmetry in the interference occurrences of oscillators

The asymmetrical configurations are stable objects of the real physical world, because they cannot annihilate. One of the most obvious asymmetry is the proton – electron mass rate $M_p = 1840\ M_e$ while they have equal charge. We explain this fact by the strong interaction of the proton, but how remember it his strong interaction ability for example in the H – atom where are only electromagnetic interactions among proton and electron.

This gives us the idea to origin the mass of proton from the electromagnetic interactions by the way interference occurrences of oscillators. The uncertainty relation of Heisenberg makes sure that the particles are oscillating.

The resultant intensity due to n equally spaced oscillators, all of equal amplitude but different from one another in phase, either because they are driven differently in phase or because we are looking at them an angle such that there is a difference in time delay:

(1) $I = I_0 \sin^2 n \phi/2$ **/** $\sin^2 \phi/2$

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

(2) $I = n^2 I_0$

This gives us the idea of

(3) $M_p = n^2 M_e$

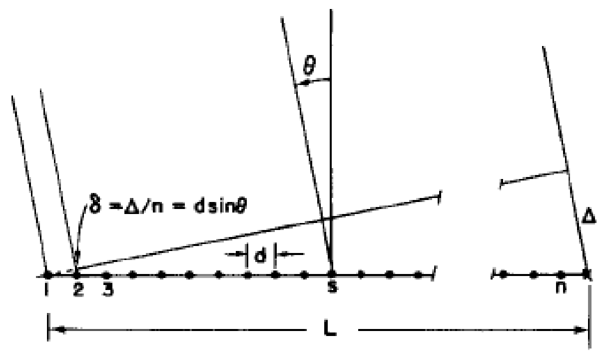


Fig. 30–3. **A linear array of *n* equal oscillators, driven with phases $\alpha_s = s\alpha$.**

Figure 1.) A linear array of n equal oscillators

There is an important feature about formula (1) which is that if the angle ϕ is increased by the multiple of 2π, it makes no difference to the formula.

So

(4) $d \sin \theta = m \lambda$

and we get m-order beam if λ less than d. [6]

If d less than λ we get only zero-order one centered at $\theta = 0$. Of course, there is also a beam in the opposite direction. The right chooses of d and λ we can ensure the conservation of charge.

For example

(5) $2 (m+1) = n$

Where 2(m+1) = N_p number of protons and n = N_e number of electrons.

In this way we can see the H_2 molecules so that 2n electrons of n radiate to 4(m+1) protons, because $d_e > \lambda_e$ for electrons, while the two protons of one H_2 molecule radiate to two electrons of them, because of $d_e < \lambda_e$ for this two protons.

To support this idea we can turn to the Planck distribution law, that is equal with the Bose – Einstein statistics.

Spontaneously broken symmetry in the Planck distribution law

The Planck distribution law is temperature dependent and it should be true locally and globally. I think that Einstein's energy-matter equivalence means some kind of existence of electromagnetic oscillations enabled by the temperature, creating the different matter formulas, atoms molecules, crystals, dark matter and energy.

Max Planck found for the black body radiation

As a function of wavelength (λ), Planck's law is written as:

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

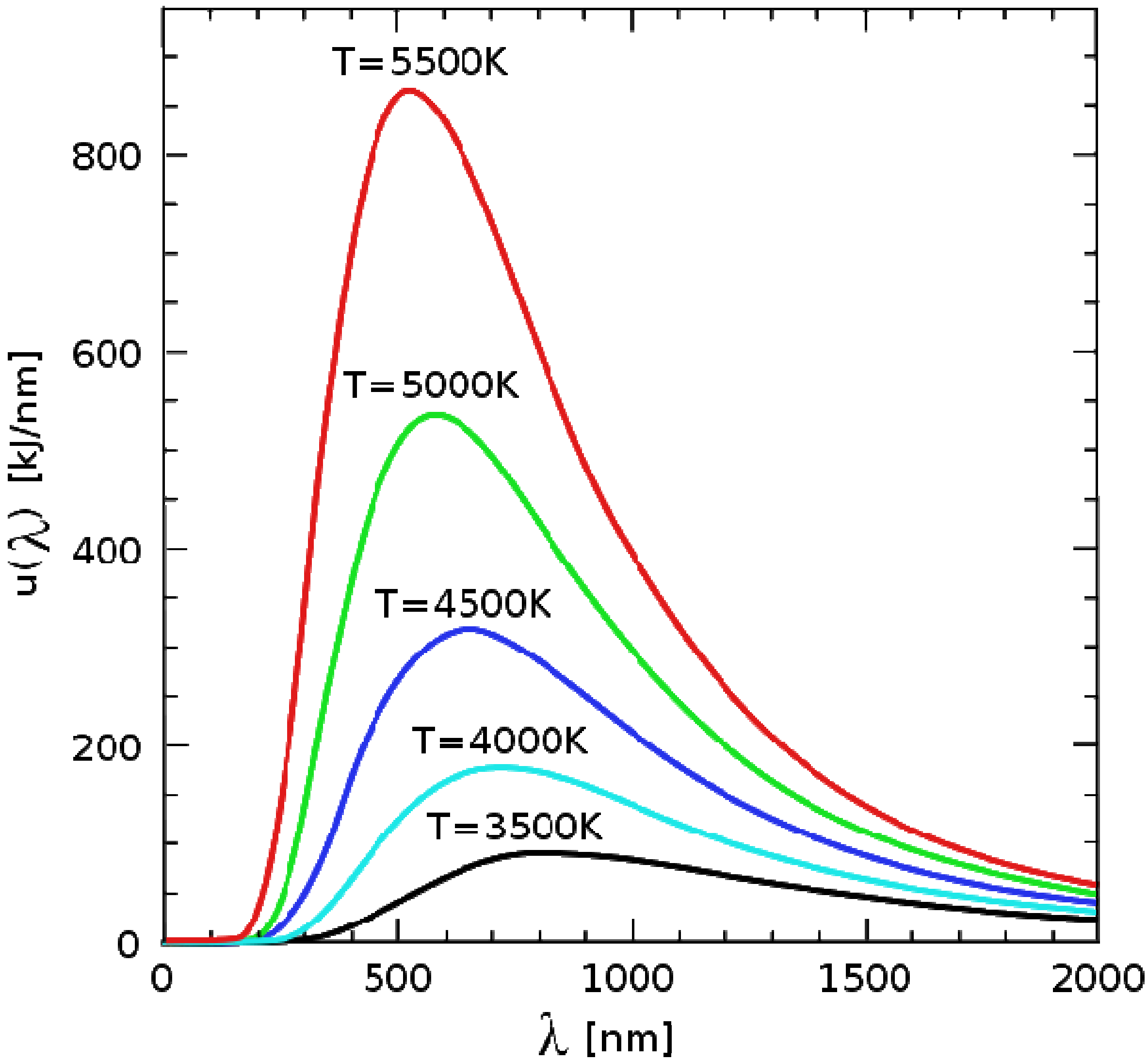


Figure 2. The distribution law for different T temperatures

We see there are two different λ_1 and λ_2 for each T and intensity, so we can find between them a d so that $\lambda_1 < d < \lambda_2$.

We have many possibilities for such asymmetrical reflections, so we have many stable oscillator configurations for any T temperature with equal exchange of intensity by radiation. All of these configurations can exist together. At the λ_{max} is the annihilation point where the configurations are symmetrical. The λ_{max} is changing by the Wien's displacement law in many textbooks.

(7) $$\lambda_{\max} = \frac{b}{T}$$

where λ_{max} is the peak wavelength, T is the absolute temperature of the black body, and b is a constant of proportionality called *Wien's displacement constant*, equal to $2.8977685(51)\times10^{-3}$ m·K (2002 CODATA recommended value).

By the changing of T the asymmetrical configurations are changing too.

The structure of the proton

We must move to the higher T temperature if we want look into the nucleus or nucleon arrive to $d<10^{-13}$ cm. If an electron with $\lambda_e < d$ move across the proton then by (5) 2 (m+1) = n with m = 0 we get n = 2 so we need two particles with negative and two particles with positive charges. If the proton can fraction to three parts, two with positive and one with negative charges, then the reflection of oscillators are right. Because this very strange reflection where one part of the proton with the electron together on the same side of the reflection, the all parts of the proton must be quasi lepton so $d > \lambda_q$. One way dividing the proton to three parts is, dividing his oscillation by the three direction of the space. We can order 1/3 e charge to each coordinates and 2/3 e charge to one plane oscillation, because the charge is scalar. In this way the proton has two +2/3 e plane oscillation and one linear oscillation with -1/3 e charge. The colors of quarks are coming from the three directions of coordinates and the proton is colorless. The flavors of quarks are the possible oscillations differently by energy and if they are plane or linear oscillations. We know there is no possible reflecting two oscillations to each other which are completely orthogonal, so the quarks never can be free, however there is an asymptotic freedom while their energy are increasing to turn them to the orthogonally. If they will be completely orthogonal then they lose this reflection and take new partners from the vacuum. Keeping the symmetry of the vacuum the new oscillations are keeping all the conservation laws, like charge, number of baryons and leptons. The all features of gluons are coming from this model. The mathematics of reflecting oscillators show Fermi statistics.

Important to mention that in the Deuteron there are 3 quarks of +2/3 and -1/3 charge, that is three u and d quarks making the complete symmetry and because this its high stability.

The Pauli Exclusion Principle says that the diffraction points are exclusive!

The Strong Interaction

Confinement and Asymptotic Freedom

For any theory to provide a successful description of strong interactions it should simultaneously exhibit the phenomena of confinement at large distances and asymptotic freedom at short distances. Lattice calculations support the hypothesis that for non-abelian gauge theories the two domains are analytically connected, and confinement and asymptotic freedom coexist.
Similarly, one way to show that QCD is the correct theory of strong interactions is that the coupling extracted at various scales (using experimental data or lattice simulations) is unique in the sense that its variation with scale is given by the renormalization group. [4]
Lattice QCD gives the same results as the diffraction theory of the electromagnetic oscillators, which is the explanation of the strong force and the quark confinement. [1]

The weak interaction

The weak interaction transforms an electric charge in the diffraction pattern from one side to the other side, causing an electric dipole momentum change, which violates the CP and time reversal symmetry.

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

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

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

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

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

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

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

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

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

The 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. [5]

Fermions and Bosons

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

The Higgs boson or Higgs particle is a proposed elementary particle in the Standard Model of particle physics. The Higgs boson's existence would have profound importance in particle physics because it would prove the existence of the hypothetical Higgs field - the simplest of several proposed explanations for the origin of the symmetry-breaking mechanism by which elementary particles gain mass. [3]

The fermions' spin

The moving charges are accelerating, since only this way can self maintain the electric field causing their acceleration. The electric charge is not point like! This constant acceleration possible if there is a rotating movement changing the direction of the velocity. This way it can accelerate forever without increasing the absolute value of the velocity in the dimension of the time and not reaching the velocity of the light.

The Heisenberg uncertainty relation says that the minimum uncertainty is the value of the spin: 1/2 h = d x d p or 1/2 h = d t d E, that is the value of the basic energy status.

What are the consequences of this in the weak interaction and how possible that the neutrinos' velocity greater than the speed of light?

The neutrino is the one and only particle doesn't participate in the electromagnetic interactions so we cannot expect that the velocity of the electromagnetic wave will give it any kind of limit.

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 source of the Maxwell equations

The electrons are accelerating also in a static electric current because of the electric force, caused by the potential difference. The magnetic field is the result of this acceleration, as you can see in [2].

The mysterious property of the matter that the electric potential difference is self maintained by the accelerating electrons in the electric current gives a clear explanation to the basic sentence of the relativity that is the velocity of the light is the maximum velocity of the matter. If the charge could move faster than the electromagnetic field than this self maintaining electromagnetic property of the electric current would be failed.

Also an interesting question, how the changing magnetic field creates a negative electric field?
The answer also the accelerating electrons will give. When the magnetic field is increasing in time by increasing the electric current, then the acceleration of the electrons will increase, decreasing the charge density and creating a negative electric force. Decreasing the magnetic field by decreasing the electric current will decrease the acceleration of the electrons in the electric current and increases the charge density, creating an electric force also working against the change.
In this way we have explanation to all interactions between the electric and magnetic forces described in the Maxwell equations.
The second mystery of the matter is the mass. We have seen that the acceleration change of the electrons in the flowing current causing a negative electrostatic force. This is the cause of the relativistic effect - built-in in the Maxwell equations - that is the mass of the electron growing with its acceleration and its velocity never can reach the velocity of light, because of this growing negative electrostatic force. The velocity of light is depending only on 2 parameters: the magnetic permeability and the electric permittivity.
There is a possibility of the polarization effect created by electromagnetic forces creates the negative and positive charges. In case of equal mass as in the electron-positron pair it is simply, but

on higher energies can be asymmetric as the electron-proton pair of neutron decay by week interaction and can be understood by the Feynman graphs.
Anyway the mass can be electromagnetic energy exceptionally and since the inertial and gravitational mass are equals, the gravitational force is electromagnetic force and since only the magnetic force is attractive between the same charges, is very important for understanding the gravitational force.

The Uncertainty Relations of Heisenberg gives the answer, since only this way can be sure that the particles are oscillating in some way by the electromagnetic field with constant energies in the atom indefinitely. Also not by chance that the uncertainty measure is equal to the fermions spin, which is one of the most important feature of the particles. There are no singularities, because 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 greatest proton mass.

The Special Relativity

The mysterious property of the matter that the electric potential difference is self maintained by the accelerating electrons in the electric current gives a clear explanation to the basic sentence of the relativity that is the velocity of the light is the maximum velocity of the matter. If the charge could move faster than the electromagnetic field than this self maintaining electromagnetic property of the electric current would be failed. [8]

The Heisenberg Uncertainty Principle

Moving faster needs stronger acceleration reducing the dx and raising the dp. It means also mass increasing since the negative effect of the magnetic induction, also a relativistic effect!

The Uncertainty Principle also explains the proton – electron mass rate since the dx is much less requiring bigger dp in the case of the proton, which is partly the result of a bigger mass m_p because of the higher electromagnetic induction of the bigger frequency (impulse).

The Gravitational force

The changing magnetic field of the changing current causes electromagnetic mass change by the negative electric field caused by the changing acceleration of the electric charge.

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 $M_p = 1840\ M_e$. 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. [1]

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 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]

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 Casimir effect

The Casimir effect is related to the Zero-point energy, which is fundamentally related to the Heisenberg uncertainty relation. The Heisenberg uncertainty relation says that the minimum uncertainty is the value of the spin: 1/2 h = dx dp or 1/2 h = dt dE, that is the value of the basic energy status.

The moving charges are accelerating, since only this way can self maintain the electric field causing their acceleration. The electric charge is not point like! This constant acceleration possible if there is a rotating movement changing the direction of the velocity. This way it can accelerate forever without increasing the absolute value of the velocity in the dimension of the time and not reaching the velocity of the light. 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 is not a point like particle, but has a real charge distribution.

Electric charge and electromagnetic waves are two sides of the same thing; the electric charge is the diffraction center of the electromagnetic waves, quantified by the Planck constant h.

The Fine structure constant

The Planck constant was first described as the proportionality constant between the energy (*E*) of a photon and the frequency (*ν*) of its associated electromagnetic wave. This relation between the energy and frequency is called the **Planck relation** or the **Planck–Einstein equation**:

$$E = h\nu\,.$$

Since the frequency ν, wavelength *λ*, and speed of light *c* are related by *λν* = *c*, the Planck relation can also be expressed as

$$E = \frac{hc}{\lambda}.$$

Since this is the source of Planck constant, the e electric charge countable from the Fine structure constant. This also related to the Heisenberg uncertainty relation, saying that the mass of the proton should be bigger than the electron mass because of the difference between their wavelengths.

The expression of the fine-structure constant becomes the abbreviated

$$\alpha = \frac{e^2}{\hbar c}$$

This is a dimensionless constant expression, 1/137 commonly appearing in physics literature.

This means that the electric charge is a result of the electromagnetic waves diffractions, consequently the proton – electron mass rate is the result of the equal intensity of the corresponding electromagnetic frequencies in the Planck distribution law, described in my diffraction theory.

Path integral formulation of Quantum Mechanics

The path integral formulation of quantum mechanics is a description of quantum theory which generalizes the action principle of classical mechanics. It replaces the classical notion of a single, unique trajectory for a system with a sum, or functional integral, over an infinity of possible trajectories to compute a quantum amplitude. [7]

It shows that the particles are diffraction patterns of the electromagnetic waves.

Conclusions

"The next natural step is then to address few-particle states and electron entanglement in quantum conductors. Again, the question of the destruction of such states by Coulomb interaction effects will be a crucial one." [9]

The magnetic induction creates a negative electric field, causing an electromagnetic inertia responsible for the relativistic mass change; it is the mysterious Higgs Field giving mass to the particles. The Planck Distribution Law of the electromagnetic oscillators explains the electron/proton mass rate by the diffraction patterns. The accelerating charges 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 Relativistic Quantum Theories. The self maintained electric potential of the accelerating charges equivalent with the General Relativity space-time curvature, and since it is true on the quantum level also, gives the base of the Quantum Gravity. The electric currents causing self maintaining electric potential is the source of the special and general relativistic effects. The Higgs Field is the result of the electromagnetic induction. The Graviton is two photons together.

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