Neutron Stars and Symmetry Violation

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Physicists have proposed a way to test quantum gravity that, in principle, could be performed by a laser-based, table-top experiment using currently available technology. [11]

Now however, a new type of materials, the so-called Weyl semimetals, similar to 3-D graphene, allow us to put the symmetry destructing quantum anomaly to work in everyday phenomena, such as the creation of electric current. [10]

Physicist Professor Chunnong Zhao and his recent PhD students Haixing Miao and Yiqiu Ma are members of an international team that has created a particularly exciting new design for gravitational wave detectors. [9]

A proposal for a gravitational-wave detector made of two space-based atomic clocks has been unveiled by physicists in the US. [8]

The gravitational waves were detected by both of the twin Laser Interferometer Gravitational-Wave Observatory (LIGO) detectors, located in Livingston, Louisiana, and Hanford, Washington, USA. [7]

A team of researchers with the University of Lisbon has created simulations that indicate that the gravitational waves detected by researchers with the LIGO project, and which are believed to have come about due to two black holes colliding, could just have easily come from another object such as a gravaster (objects which are believed to have their insides made of dark energy) or even a wormhole. In their paper published in Physical Review Letters, the team describes the simulations they created, what was seen and what they are hoping to find in the future. [6]

In a landmark discovery for physics and astronomy, international scientists said Thursday they have glimpsed the first direct evidence of gravitational waves, or ripples in space-time, which Albert Einstein predicted a century ago.

[5]

Scientists at the National Institute for Space Research in Brazil say an undiscovered type of matter could be found in neutron stars (illustration shown). Here matter is so dense that it could be 'squashed' into strange matter. This would create an entire 'strange star' - unlike anything we have seen. [4]

The changing acceleration of the electrons explains the created negative electric field of the magnetic induction, the electromagnetic inertia, the changing relativistic mass and the Gravitational Force, giving a Unified Theory of the physical forces. Taking into account the Planck Distribution Law of the electromagnetic oscillators also, we can explain the electron/proton mass rate and the Weak and Strong Interactions.

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Author: George Rajna

Preface

Today the most popular enigma is the gravitational force after founding the Higgs boson experimentally. Although the graviton until now is a theoretical particle, its existence is a necessary basis of the Quantum Gravitation and the Theory of Everything.

The electromagnetic origin of mass gives an explanation of the inertia, the relativistic change of mass and also the gravitational force.

'Strange' glimpse into neutron stars and symmetry violation

New results from precision particle detectors at the Relativistic Heavy Ion Collider (RHIC) offer a fresh glimpse of the particle interactions that take place in the cores of neutron stars and give nuclear physicists a new way to search for violations of fundamental symmetries in the universe. The results, just published in *Nature Physics*, could only be obtained at a powerful ion collider such as RHIC, a U.S. Department of Energy (DOE) Office of Science user facility for nuclear physics research at DOE's Brookhaven National Laboratory.

The precision measurements reveal that the binding energy holding together the components of the simplest "strange-matter" nucleus, known as a "hypertriton," is greater than obtained by previous, less-precise experiments. The new value could have important astrophysical implications for understanding the properties of neutron stars, where the presence of particles containing so-called "strange" quarks is predicted to be common.

The second measurement was a search for a difference between the mass of the hypertriton and its antimatter counterpart, the antihypertriton (the first nucleus containing an antistrange quark, discovered at RHIC in 2010). Physicists have never found a mass difference between matter-antimatter partners so seeing one would be a big discovery. It would be evidence of "CPT" violation—a simultaneous violation of three fundamental symmetries in nature pertaining to the reversal of charge, parity (mirror symmetry), and time.

"Physicists have seen parity violation, and violation of CP together (each earning a Nobel Prize for Brookhaven Lab[—]), but never CPT," said Brookhaven physicist Zhangbu Xu, co-spokesperson of RHIC's STAR experiment, where the hypertriton research was done.

But no one has looked for CPT violation in the hypertriton and antihypertriton, he said, "because no one else could yet."

The previous CPT test of the heaviest nucleus was performed by the ALICE collaboration at Europe's Large Hadron Collider (LHC), with a measurement of the mass difference between ordinary helium-3 and antihelium-3. The result, showing no significant difference, was published in *Nature Physics* in 2015.

Spoiler alert: The STAR results also reveal no significant mass difference between the matter-antimatter partners explored at RHIC, so there's still no evidence of CPT violation. But the fact that STAR physicists could even make the measurements is a testament to the remarkable capabilities of their detector.

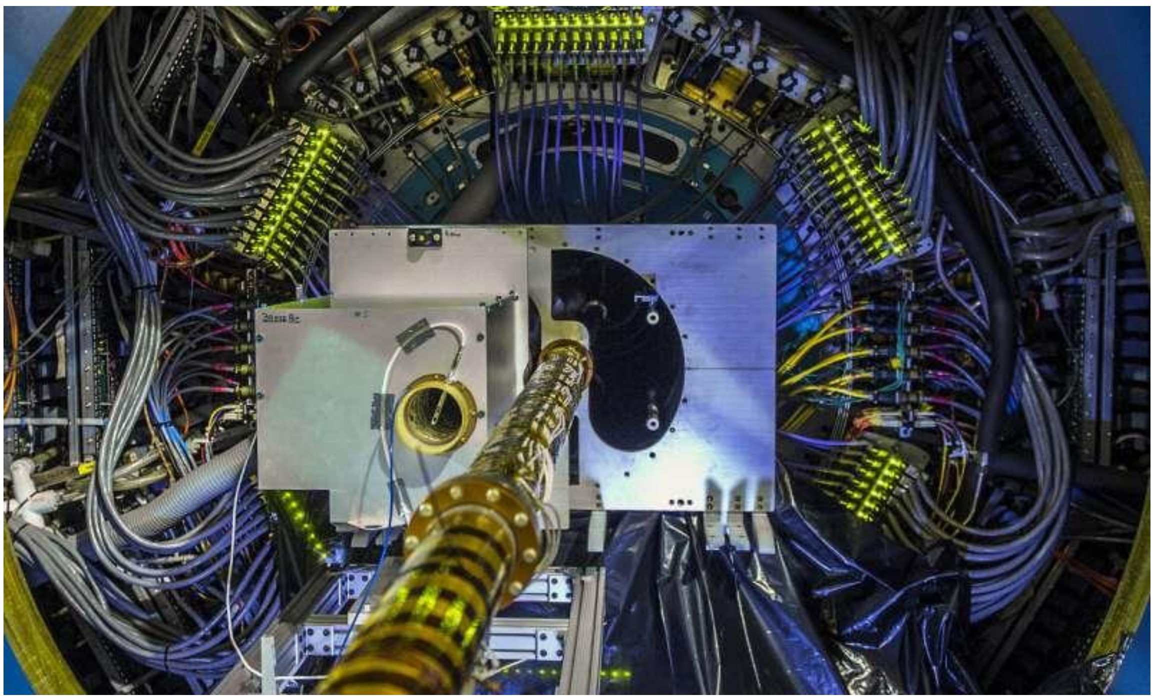
Strange matter

The simplest normal-matter nuclei contain just protons and neutrons, with each of those particles made of ordinary "up" and "down" quarks. In hypertritons, one neutron is replaced by a particle called a lambda, which contains one strange quark along with the ordinary up and down varieties.

Such strange matter replacements are common in the ultra-dense conditions created in RHIC's collisions—and are also likely in the cores of neutron stars where a single teaspoon of matter would weigh more than 1 billion tons. That's because the high density makes it less costly energy-wise to make strange quarks than the ordinary up and down varieties.

For that reason, RHIC collisions give nuclear physicists a way to peer into the subatomic interactions within distant stellar objects without ever leaving Earth. And because RHIC collisions create hypertritons and antihypertritons in nearly equal amounts, they offer a way to search for CPT violation as well.

But finding those rare particles among the thousands that stream from each RHIC particle smashup—with collisions happening thousands of times each second—is a daunting task. Add to the challenge the fact that these unstable particles decay almost as soon as they form—within centimeters of the center of the four-meter-wide STAR detector.



The Heavy Flavor Tracker at the center of RHIC's STAR detector. Credit: Brookhaven National Laboratory

Precision detection

Fortunately, detector components added to STAR for tracking different kinds of particles made the search a relative cinch. These components, called the "Heavy-Flavor Tracker," are located very close to the STAR detector's center. They were developed and built by a team of STAR collaborators led by scientists and engineers at DOE's Lawrence Berkeley National Laboratory (Berkeley Lab). These inner components allow scientists to match up tracks created by decay products of each hypertriton and antihypertriton with their point of origin just outside the collision zone.

"What we look for are the 'daughter' particles—the decay products that strike detector components at the outer edges of STAR," said Berkeley Lab physicist Xin Dong. Identifying tracks of pairs or triplets of daughter particles that originate from a single point just outside the primary collision zone allows the scientists to pick these signals out from the sea of other particles streaming from each RHIC collision.

"Then we calculate the momentum of each daughter particle from one decay (based on how much they bend in STAR's magnetic field), and from that we can reconstruct their masses and the mass of the parent hypertriton or antihypertriton particle before it decayed," explained Declan Keane of Kent State University (KSU). Telling the hypertriton and antihypertriton apart is easy because they decay into different daughters, he added.

"Keane's team, including Irakli Chakeberia, has specialized in tracking these particles through the detectors to 'connect the dots,'" Xu said. "They also provided much needed visualization of the events."

As noted, compiling data from many collisions revealed no mass difference between the matter and antimatter hypernuclei, so there's no evidence of CPT violation in these results.

But when STAR physicists looked at their results for the binding energy of the hypertriton, it turned out to be larger than previous measurements from the 1970s had found.

The STAR physicists derived the binding energy by subtracting their value for the hypertriton mass from the combined known masses of its building-block particles: a deuteron (a bound state of a proton and a neutron) and one lambda.

"The hypertriton weighs less than the sum of its parts because some of that mass is converted into the energy that is binding the three nucleons together," said Fudan University STAR collaborator Jinhui Chen, whose Ph.D. student, Peng Liu, analyzed the large datasets to arrive at these results. "This binding energy is really a measure of the strength of these interactions, so our new measurement could have important implications for understanding the 'equation of state' of neutron stars," he added.

For example, in model calculations, the mass and structure of a neutron star depends on the strength of these interactions. "There's great interest in understanding how these interactions—a form of the strong force—are different between ordinary nucleons and strange nucleons containing up, down, and strange quarks," Chen said. "Because these hypernuclei contain a single lambda, this is one of the best ways to make comparisons with theoretical predictions. It reduces the problem to its simplest form." [14]

Study identifies a transition in the strong nuclear force that illuminates the structure of a neutron star's core

Most ordinary matter is held together by an invisible subatomic glue known as the strong nuclear force—one of the four fundamental forces in nature, along with gravity, electromagnetism, and the weak force. The strong nuclear force is responsible for the push and pull between protons and neutrons in an atom's nucleus, which keeps an atom from collapsing in on itself.

In atomic nuclei, most protons and neutrons are far enough apart that physicists can accurately predict their interactions. However, these predictions are challenged when the subatomic particles are so close as to be practically on top of each other.

While such ultrashort-distance interactions are rare in most matter on Earth, they define the cores of neutron stars and other extremely dense astrophysical objects. Since scientists first began exploring nuclear physics, they have struggled to explain how the strong nuclear force plays out at such ultrashort distances.

Now physicists at MIT and elsewhere have for the first time characterized the strong nuclear force, and the interactions between protons and neutrons, at extremely short distances.

They performed an extensive data analysis on previous particle accelerator experiments, and found that as the distance between protons and neutrons becomes shorter, a surprising transition occurs in their interactions. Where at large distances, the strong nuclear force acts primarily to attract a proton to a neutron, at very short distances, the force becomes essentially indiscriminate: Interactions can occur not just to attract a proton to a neutron, but also to repel, or push apart pairs of neutrons.

"This is the first very detailed look at what happens to the strong nuclear force at very short distances," says Or Hen, assistant professor of physicist at MIT. "This has huge implications, primarily for neutron stars and also for the understanding of nuclear systems as a whole."

Hen and his colleagues have published their results in the journal *Nature*. His co-authors include first author Axel Schmidt Ph.D. '16, a former graduate student and postdoc, along with graduate student Jackson Pybus, undergraduate student Adin Hrnjic and additional colleagues from MIT, the Hebrew University, Tel-Aviv University, Old Dominion University, and members of the CLAS Collaboration, a multi-institutional group of scientists involved with the CEBAF Large Accelerator Spectrometer (CLAS), a particle accelerator at Jefferson Laboratory in Newport News, Virginia.

Star drop snapshot

Ultra-short-distance interactions between protons and neutrons are rare in most atomic nuclei. Detecting them requires pummeling atoms with a huge number of extremely high-energy electrons, a fraction of which might have a chance of kicking out a pair of nucleons (protons or neutrons) moving at high momentum—an indication that the particles must be interacting at extremely short distances.

"To do these experiments, you need insanely high-current particle accelerators," Hen says. "It's only recently where we have the detector capability, and understand the processes well enough to do this type of work."

Hen and his colleagues looked for the interactions by mining data previously collected by CLAS, a house-sized particle detector at Jefferson Laboratory; the JLab accelerator produces unprecedently high intensity and high-energy beams of electrons. The CLAS detector was operational from 1988 to 2012, and the results of those experiments have since been available for researchers to look through for other phenomena buried in the data.

In their new study, the researchers analyzed a trove of data, amounting to some quadrillion electrons hitting atomic nuclei in the CLAS detector. The electron beam was aimed at foils made from carbon, lead, aluminum, and iron, each with atoms of varying ratios of protons to neutrons. When an electron collides with a proton or neutron in an atom, the energy at which it scatters away is proportional to the energy and momentum of the corresponding nucleon.

"If I know how hard I kicked something and how fast it came out, I can reconstruct the initial momentum of the thing that was kicked," Hen explains.

With this general approach, the team looked through the quadrillion electron collisions and managed to isolate and calculate the momentum of several hundred pairs of high-momentum nucleons. Hen likens these pairs to "neutron star droplets," as their momentum, and their inferred distance between each other, is similar to the extremely dense conditions in the core of a neutron star.

They treated each isolated pair as a "snapshot" and organized the several hundred snapshots along a momentum distribution. At the low end of this distribution, they observed a suppression of proton-proton pairs, indicating that the strong nuclear force acts mostly to attract protons to neutrons at intermediate high-momentum, and short distances.

Further along the distribution, they observed a transition: There appeared to be more proton-proton and, by symmetry, neutron-neutron pairs, suggesting that, at higher momentum, or increasingly short distances, the strong nuclear force acts not just on protons and neutrons, but also on protons and protons and neutrons and neutrons. This pairing force is understood to be repulsive in nature, meaning that at short distances, neutrons interact by strongly repelling each other.

"This idea of a repulsive core in the strong nuclear force is something thrown around as this mythical thing that exists, but we don't know how to get there, like this portal from another realm," Schmidt says. "And now we have data where this transition is staring us in the face, and that was really surprising."

The researchers believe this transition in the strong nuclear force can help to better define the structure of a neutron star. Hen previously found evidence that in the outer core of neutron stars, neutrons mostly pair with protons through the strong attraction. With their new study, the researchers have found evidence that when particles are packed in much denser configurations and separated by shorter distances, the strong nuclear force creates a repulsive force between neutrons that, at a neutron star's core, helps keep the star from collapsing in on itself.

Less than a bag of quarks

The team made two additional discoveries. For one, their observations match the predictions of a surprisingly simple model describing the formation of short-ranged correlations due to the strong nuclear force. For another, against expectations, the core of a neutron star can be described strictly by the interactions between protons and neutrons, without needing to explicitly account for more complex interactions between the quarks and gluons that make up individual nucleons.

When the researchers compared their observations with several existing models of the strong nuclear force, they found a remarkable match with predictions from Argonne V18, a model developed by a research group at Argonne National Laboratory, that considered 18 different ways nucleons may interact, as they are separated by shorter and shorter distances.

This means that if scientists want to calculate properties of a neutron star, Hen says they can use this particular Argonne V18 model to accurately estimate the strong nuclear force interactions between pairs of nucleons in the core. The new data can also be used to benchmark alternate approaches to modeling the cores of neutron stars.

What the researchers found most exciting was that this same model, as it is written, describes the interaction of nucleons at extremely short distances, without explicitly taking into account quarks and gluons. Physicists had assumed that in extremely dense, chaotic environments such as neutron star cores, interactions between neutrons should give way to the more complex forces between quarks and gluons. Because the model does not take these more complex interactions into account, and because its predictions at short distances match the team's observations, Hen says it's likely that a neutron star's core can be described in a less complicated manner.

"People assumed that the system is so dense that it should be considered as a soup of quarks and gluons," Hen explains. "But we find even at the highest densities, we can describe these interactions using protons and neutrons; they seem to keep their identities and don't turn into this bag of quarks. So the cores of neutron stars could be much simpler than people thought. That's a huge surprise." [13]

Neutrons probe gravity's inverse square law

A spallation neutron source has been used by physicists in Japan to search for possible violations of the inverse square law of gravity. By scattering neutrons off noble-gas nuclei, the researchers found no evidence of any deviation from the tried and tested formula. However, they could slightly reduce the wiggle room for any non-conventional interactions at distances of less than 0.1 nm, and are confident they can boost the sensitivity of their experiment over the next few months.

According to Newton's law of universal gravitation, the gravitational force between two objects is proportional to each of their masses and inversely proportional to the square of the distance between them. This relationship can also be derived using general relativity, when the field involved is fairly weak and objects are travelling significantly slower than the speed of light. However, there are many speculative theories – some designed to provide a quantum description of gravity – that predict that the relationship breaks down at small distances.

Physicists have done a wide range of different experiments to look for such a deviation. These include torsion balances, which measure the tiny gravitational attraction between two masses suspended on a fibre and two fixed masses. However, this approach is limited by environmental noise such as seismic vibrations and even the effects of dust particles. As a result such experiments cannot probe gravity at very short distances, with the current limit being about 0.01 mm.

Scattered in all directions

Neutrons, on the other hand, can get down to the nanoscale and beyond. The idea is to fire a beam of neutrons at a gas and record how the neutrons are scattered by the constituent nuclei. In the absence of any new forces modifying gravity at short scales, the neutrons and nuclei essentially only interact via the strong force (neutrons being electrically neutral). But the strong force acts over extremely short distances – roughly the size of the nucleus, about 10^{-14} m – while the neutrons have a de Broglie wavelength of around 1 nm. The neutrons therefore perceive the nuclei as point sources and as such are scattered equally in all directions.

Any new force, however, would likely extend beyond the nucleus. If its range were comparable to the neutrons' wavelength then those neutrons would be scattered more frequently in a forward direction than at other angles. Evidence of such a force, should it exist, can therefore be sought by firing in large numbers of neutrons and measuring the distribution of their scattering angles.

In 2008, Valery Nesvizhevsky of the Institut Laue-Langevin in France and colleagues looked for evidence of such forward scattering in data from previous neutron experiments. They ended up empty handed but could place new upper limits on the strength of any new forces, improving on the existing constraints for scales between 1 pm and 5 nm by several orders of magnitude. Those limits were then pushed back by about another order of magnitude two years ago, when Sachio Komamiya at the University of Tokyo and team scattered neutrons off atomic xenon at the HANARO research reactor at the Korean Atomic Energy Research Institute in South Korea.

Time of flight

In the new research, Tamaki Yoshioka of Kyushu University in Japan and colleagues use neutrons from a spallation source at the Japan Proton Accelerator Research Complex (J-PARC) in Tokai, which they fire at samples of xenon and helium. Because the J-PARC neutrons come in pulses, the researchers can easily measure their time of flight, and, from that, work out their velocity and hence their wavelength.

Armed with this information, the team can establish whether any forward scattering is due to a new force or simply caused by neutrons bouncing off larger objects in the gas, such as trace amounts of atmospheric gases. At any given wavelength, both types of scattering would be skewed in the forward direction and so would be indistinguishable from one another. But across a range of wavelengths different patterns would emerge. For atmospheric gases, the scattering angle would simply be proportional to the neutrons' wavelength. In the case of a new force, on the other hand, the relationship would be more complex because the effective size of the nucleus would itself vary with neutron wavelength.

Reactors can also be used to generate pulses, by "chopping" a neutron beam. But that process severely limits the beam's intensity. Taking advantage of the superior statistics at J-PARC, Yoshioka and colleagues were able to reduce the upper limit on any new forces below 0.1 nm by about an order of magnitude over the HANARO results – showing that their inherent strength can at most be 10^{24} times that of gravity's (gravity being an exceptionally weak force).

Cost-effective search

That is still nowhere near the sensitivity of torsion balance searches at bigger scales – which can get down to the strength of gravity itself. As Nesvizhevsky points out, torsion balances use macroscopic masses with "Avogadro numbers" (10^{23}) of atoms, whereas neutron scattering experiments involve at most a few tens of millions of neutrons. Nevertheless, he believes that the new line of research is well worth pursuing, pointing out that many theories positing additional gravity-like forces “predict forces in this range of observations”. Such experiments, he argues, represent “an extremely cost-effective way of looking for a new fundamental force” when compared to searches carried out in high-energy physics.

Spurred on by the prospect of discovery, Yoshioka and colleagues are currently taking more data. The lead author of a preprint on *arXiv*describing the latest research, Christopher Haddock of Nagoya University, says that they hope to have new results by the summer. A series of improvements to the experiment, including less scattering from the beam stop, he says, could boost sensitivity to new forces in the sub-nanometre range by up to a further order of magnitude and should also improve existing limits at distances of up to 10 nm. [12]

Physicists propose test of quantum gravity using current technology

Physicists have proposed a way to test quantum gravity that, in principle, could be performed by a laser-based, table-top experiment using currently available technology. Although a theory of quantum gravity would overcome one of the biggest challenges in modern physics by unifying general relativity and quantum mechanics, currently physicists have no way of testing any proposed theories of quantum gravity.

Now a team of seven physicists from various countries, S. Dey, A. Bhat, D. Momeni, M. Faizal, A. F. Ali, T. K. Dey, and A. Rehman, have come up with a novel way to experimentally test quantum gravity using a laser-based experiment. They have published a paper on their proposed test in a recent issue of Nuclear Physics B.

One reason why testing quantum gravity is so challenging is that its effects appear only at very highenergy scales and their corresponding tiny length scales. These extreme scales, which are very near the Planck scale, are roughly 15 orders of magnitude beyond those accessible by the Large Hadron Collider (LHC), by far the world's highest-energy experiment.

In order to address these challenges, the physicists took a completely different approach to reaching Planck-scale energies and lengths, which is by measuring the effects of a property called noncommutativity.

Many proposed theories of quantum gravity, including loop quantum gravity and string theory, are noncommutative theories, in which spacetime geometry is noncommutative. In this framework, certain parameters have noncommutative relations, a concept that is closely related to the idea of complementary variables in Heisenberg's uncertainty principle. One of the consequences of a noncommutative spacetime is that there are no singularities, which has implications for other areas of cosmology, such as the big bang and black holes.

With their proposed test, the physicists' goal is to find experimental evidence supporting the idea that spacetime does indeed have a noncommutative structure. To do this, the proposed test attempts to detect any changes in the conventional commutative relations occurring in a micromechanical oscillator. If these changes are present, they would indicate a noncommutative structure and produce a measurable optical phase shift on a light pulse that has been coupled to the oscillator.

Using current optical setups, this phase shift can be measured with sufficiently high levels of accuracy that, according to the physicists' calculations, would make it possible to access the energy scale near the Planck length. By accessing this scale, the experiment could potentially probe the effects of noncommutative theories at the energy regime relevant to quantum gravity.

"We expect the geometry of spacetime to be an emergent structure, which emerges from some purely mathematical theory of quantum gravity," coauthor Mir Faizal, a professor at the University of British Columbia-Okanagan and the University of Lethbridge, Canada, told Phys.org. "This is similar to the geometry of a metal rod emerging from atomic physics. It has been suggested from various approaches to quantum gravity that this structure underlying the geometry of spacetime can be represented by noncommutative geometry. So, we have proposed a way to test this idea using an opto-mechaical experiment. The advantage of having such a structure will be that, in it, the spacetime will be free of singularities, including the big bang singularity." [11]

Scientists observe gravitational anomaly on Earth

Modern physics has accustomed us to strange and counterintuitive notions of reality—especially quantum physics which is famous for leaving physical objects in strange states of superposition. For example, Schrödinger's cat, who finds itself unable to decide if it is dead or alive. Sometimes however quantum mechanics is more decisive and even destructive.

Symmetries are the holy grail for physicists. Symmetry means that one can transform an object in a certain way that leaves it invariant. For example, a round ball can be rotated by an arbitrary angle, but always looks the same. Physicists say it is symmetric under rotations. Once the symmetry of a physical system is identified it's often possible to predict its dynamics.

Sometimes however the laws of quantum mechanics destroy a symmetry that would happily exist in a world without quantum mechanics, i.e classical systems. Even to physicists this looks so strange that they named this phenomenon an "anomaly."

For most of their history, these quantum anomalies were confined to the world of elementary particle physics explored in huge accelerator laboratories such as Large Hadron Collider at CERN in Switzerland. Now however, a new type of materials, the so-called Weyl semimetals, similar to 3-D graphene, allow us to put the symmetry destructing quantum anomaly to work in everyday phenomena, such as the creation of electric current.

In these exotic materials electrons effectively behave in the very same way as the elementary particles studied in high energy accelerators. These particles have the strange property that they cannot be at rest—they have to move with a constant speed at all times. They also have another property called spin. It is like a tiny magnet attached to the particles and they come in two species. The spin can either point in the direction of motion or in the opposite direction.

When one speaks of right- and left-handed particles this property is called chirality. Normally the two different species of particles, identical except for their chirality (handedness), would come with separate symmetries attached to them and their numbers would be separately conserved. However, a quantum anomaly can destroy their peaceful coexistence and changes a left-handed particle into a right-handed one or vice-versa.

Appearing in a paper published today in Nature, an international team of physicists, material scientists and string theoreticians, have observed such a material, an effect of a most exotic quantum anomaly that hitherto was thought to be triggered only by the curvature of space-time as described by Einstein's theory of relativity. But to the surprise of the team, they discovered it also exists on Earth in the properties of solid state physics, which much of the computing industry is based on, spanning from tiny transistors to cloud data centers.

"For the first time, we have experimentally observed this fundamental quantum anomaly on Earth which is extremely important towards our understanding of the universe," said Dr. Johannes Gooth, an IBM Research scientist and lead author of the paper. "We can now build novel solid-state devices based on this anomaly that have never been considered before to potentially circumvent some of the problems inherent in classical electronic devices, such as transistors."

New calculations, using in part the methods of string theory, showed that this gravitational anomaly is also responsible for producing a current if the material is heated up at the same time a magnetic field is applied.

"This is an incredibly exciting discovery. We can clearly conclude that the same breaking of symmetry can be observed in any physical system, whether it occurred at the beginning of the universe or is happening today, right here on Earth," said Prof. Dr. Karl Landsteiner, a string theorist at the Instituto de Fisica Teorica UAM/CSIC and co-author of the paper.

IBM scientists predict this discovery will open up a rush of new developments around sensors, switches and thermoelectric coolers or energy-harvesting devices, for improved power consumption. [10]

Physicists use Einstein's 'spooky' entanglement to invent supersensitive gravitational wave detector

The first direct detection of gravitational waves, a phenomenon predicted by Einstein's 1915 general theory of relativity, was reported by scientists in 2016.

Armed with this "discovery of the century", physicists around the world have been planning new and better detectors of gravitational waves.

Physicist Professor Chunnong Zhao and his recent PhD students Haixing Miao and Yiqiu Ma are members of an international team that has created a particularly exciting new design for gravitational wave detectors.

The new design is a real breakthrough because it can measure signals below a limit that was previously believed to be an insurmountable barrier. Physicists call this limit the standard quantum limit. It is set by the quantum uncertainty principle.

The new design, published in Nature magazine this week, shows that this may not be a barrier any longer.

Using this and other new approaches may allow scientists to monitor black hole collisions and "spacequakes" across the whole of the visible universe.

How gravitational wave detectors work

Gravitational waves are not vibrations travelling through space, but rather vibrations of space itself. They have already told us about an unexpectedly large population of black holes. We hope that further study of gravitational waves will help us to better understand our universe.

But the technologies of gravitational wave detectors are likely to have enormous significance beyond this aspect of science, because in themselves they are teaching us how to measure unbelievably tiny amounts of energy.

Gravitational wave detectors use laser light to pick up tiny vibrations of space created when black holes collide. The collisions create vast gravitational explosions. They are the biggest explosions known in the universe, converting mass directly into vibrations of pure space.

It takes huge amounts of energy to make space bend and ripple. Our detectors – exquisitely perfect devices that use big heavy mirrors with scarily powerful lasers – must measure space stretching by a mere billionth of a billionth of a metre over the four kilometre scale of our detectors. These measurements already represent the smallest amount of energy ever measured.

But for gravitational wave astronomers this is not good enough. They need even more sensitivity to be able to hear many more predicted gravitational "sounds", including the sound of the moment the universe was created in the big bang.

This is where the new design comes in.

A spooky idea from Einstein

The novel concept is founded on original work from Albert Einstein.

In 1935 Albert Einstein and co-workers Boris Podolsky and Nathan Rosen tried to depose the theory of quantum mechanics by showing that it predicted absurd correlations between widely spaced particles.

Einstein proved that if quantum theory was correct, then pairs of widely spaced objects could be entangled like two flies tangled up in a spider's web. Weirdly, the entanglement did not diminish, however far apart you allowed the objects to move.

Einstein called entanglement "spooky action at a distance". He was sure that his discovery would do away with the theory of quantum mechanics once and for all, but this was not to be.

Since the 1980s physicists have demonstrated time and again that quantum entanglement is real. However much he hated it, Einstein's prediction was right and to his chagrin, quantum theory was correct. Things at a distance could be entangled.

Today physicists have got used to the "spookiness", and the theory of entanglement has been harnessed for the sending of secret codes that cannot be intercepted.

Around the world, organisations such as Google and IBM and academic laboratories are trying to create quantum computers that depend on entanglement.

And now Zhao and colleagues want to use the concept of entanglement to create the new gravitational wave detector's design.

A new way to measure gravitational waves

The exciting aspect of the new detector design is that it is actually just a new way of operating existing detectors. It simply uses the detector twice.

One time, photons in the detector are altered by the gravitational wave so as to pick up the waves. The second time, the detector is used to change the quantum entanglement in such a way that the noise due to quantum uncertainty is not detected.

The only thing that is detected is the motion of the distant mirrors caused by the gravitational wave. The quantum noise from the uncertainty principle does not appear in the measurement.

To make it work, you have to start with entangled photons that are created by a device called a quantum squeezer. This technology was pioneered for gravitational wave astronomy at Australian National University, and is now an established technique.

Like many of the best ideas, the new idea is a very simple one, but one that took enormous insight to recognise. You inject a miniscule amount of squeezed light from a quantum squeezer, and use it twice!

Around the world physicists are getting ready to test the new theory and find the best way of implementing it in their detectors. One of these is the GEO gravitational wave detector at Hannover in Germany, which has been a test bed for many of the new technologies that allowed last year's momentous discovery of gravitational waves. [9]

Atomic clocks in space could detect gravitational waves

A proposal for a gravitational-wave detector made of two space-based atomic clocks has been unveiled by physicists in the US. The scheme involves placing two atomic clocks in different locations around the Sun and using them to measure tiny shifts in the frequency of a laser beam shone from one clock to the other. The designers claim that the detector will complement the LISA space-based gravitational-wave detector, which is expected to launch in 2034.

Gravitational waves are ripples in the fabric of space–time that are created when masses are accelerated. In February of this year, the LIGO collaboration announced the first-ever direct detection of gravitational waves – from the merger of two black holes – using a pair of kilometresized interferometers in the US. Just last week, a second detection was announced by LIGO from a different black-hole merger.

Now, Shimon Kolkowitz and Jun Ye of JILA in Colorado have joined forces with Mikhail Lukin and colleagues at Harvard University to come up with a proposal for detecting gravitational waves using two space-based atomic clocks. Each device would be an optical-lattice atomic clock, which is an extremely precise timekeeper that uses the frequency of an atomic transition to measure time. The atoms are trapped within a 1D optical lattice that is a standing wave created by reflecting laser light from a mirror. This is a very effective way of shielding the atoms from external noise that can degrade clock performance.

Locked lasers

Each satellite will also contain an ultra-stable laser, the light from which will be fired from one satellite to the other and vice versa. Optical systems aboard the satellites will lock the two lasers to a single frequency, essentially creating a single laser operating at a single frequency.

When a gravitational wave propagates through the solar system it will cause a periodic, relative motion between the satellites, bringing them closer together, then farther apart, and then closer together again. This motion will result in a Doppler shift of the laser light as it travels between the spacecraft – with the frequency of the light increasing slightly when the satellites move together and decreasing slightly when the satellites move apart.

In the proposal, this motion will be detected by using the atomic clock in one satellite – called "A" – to measure the frequency of its outgoing laser light. The atomic clock at satellite B will then measure the frequency of the incoming laser light from A. Because the atomic clocks are identical, any difference in the frequencies measured at A and B could only be caused by a gravitational wave – assuming that all other relative motions of the satellites have been reduced to an appropriate level.
"It's these small periodic shifts in the laser frequency that we hope to detect," says Kolkowitz.

Narrow-band detection

Unlike LISA, which will be able to detect gravitational waves over a relatively wide band of frequencies (0.03–100 mHz), the proposed atomic-clock detector will be narrow-band in nature and will work best for signals at around 3 mHz. While this alone offers no real benefit over LISA – which also has its maximum sensitivity in the millihertz range – Kolkowitz says that the narrow operational "window" of the detector can be shifted along, from 3 mHz to as high as 10 Hz, without significant loss in sensitivity. This tuning could be done by adjusting the process whereby the atomic clocks measure the laser frequencies.

This could prove to be very useful, because much of the tuneable range falls outside of the capabilities of both LIGO and LISA . This means that the gravitational waves from a binary black-hole merger could be first detected by LISA several years before the merger occurs – when the black holes are radiating gravitational waves at millihertz frequencies. As time progresses towards the merger, the frequency of the gravitational waves will increase and move beyond LISA's operational band. "Using our detector's tunable narrowband mode, you could continue to detect and track the gravitational waves all the way up to the point when they would become visible to LIGO," says Kolkowitz.

Clocks on board

Kolkowitz and colleagues believe that their design could be integrated into the LISA spacecraft. "We hope that our proposal offers some motivation to consider putting optical lattice atomic clocks on board," he says. Kolkowitz also points out that a network of such clocks in space would allow physicists to perform new tests of fundamental laws of nature and searches for unknown physics.

Tim Sumner of Imperial College London works on LISA, and thinks that it is highly unlikely ESA would want to go with a completely new technology/implementation at this stage. Instead, he thinks an atomic-clock-based gravitational-wave detector could be considered for a future mission. [8]

Gravitational waves detected from second pair of colliding black holes

The gravitational waves were detected by both of the twin Laser Interferometer Gravitational-Wave Observatory (LIGO) detectors, located in Livingston, Louisiana, and Hanford, Washington, USA.

The LIGO Observatories are funded by the National Science Foundation (NSF), and were conceived, built, and are operated by Caltech and MIT. The discovery, accepted for publication in the journal Physical Review Letters, was made by the LIGO Scientific Collaboration (which includes the GEO Collaboration and the Australian Consortium for Interferometric Gravitational Astronomy) and the Virgo Collaboration using data from the two LIGO detectors.

Gravitational waves carry information about their origins and about the nature of gravity that cannot otherwise be obtained, and physicists have concluded that these gravitational waves were produced during the final moments of the merger of two black holes—14 and 8 times the mass of the sun—to produce a single, more massive spinning black hole that is 21 times the mass of the sun.

"It is very significant that these black holes were much less massive than those observed in the first detection," says Gabriela González, LIGO Scientific Collaboration (LSC) spokesperson and professor of physics and astronomy at Louisiana State University. "Because of their lighter masses compared to the first detection, they spent more time—about one second—in the sensitive band of the detectors. It is a promising start to mapping the populations of black holes in our universe."

During the merger, which occurred approximately 1.4 billion years ago, a quantity of energy roughly equivalent to the mass of the sun was converted into gravitational waves. The detected signal comes from the last 27 orbits of the black holes before their merger. Based on the arrival time of the signals—with the Livingston detector measuring the waves 1.1 milliseconds before the Hanford detector—the position of the source in the sky can be roughly determined.

"In the near future, Virgo, the European interferometer, will join a growing network of gravitational wave detectors, which work together with ground-based telescopes that follow-up on the signals," notes Fulvio Ricci, the Virgo Collaboration spokesperson, a physicist at Istituto Nazionale di Nucleare (INFN) and professor at Sapienza University of Rome. "The three interferometers together will permit a far better localization in the sky of the signals."

The first detection of gravitational waves, announced on February 11, 2016, was a milestone in physics and astronomy; it confirmed a major prediction of Albert Einstein's 1915 general theory of relativity, and marked the beginning of the new field of gravitational-wave astronomy.

The second discovery "has truly put the 'O' for Observatory in LIGO," says Caltech's Albert Lazzarini, deputy director of the LIGO Laboratory. "With detections of two strong events in the four months of our first observing run, we can begin to make predictions about how often we might be hearing gravitational waves in the future.

LIGO is bringing us a new way to observe some of the darkest yet most energetic events in our universe."

"We are starting to get a glimpse of the kind of new astrophysical information that can only come from gravitational wave detectors," says MIT's David Shoemaker, who led the Advanced LIGO detector construction program.

Both discoveries were made possible by the enhanced capabilities of Advanced LIGO, a major upgrade that increases the sensitivity of the instruments compared to the first generation LIGO detectors, enabling a large increase in the volume of the universe probed.

"With the advent of Advanced LIGO, we anticipated researchers would eventually succeed at detecting unexpected phenomena, but these two detections thus far have surpassed our expectations," says NSF Director France A. Córdova. "NSF's 40-year investment in this foundational research is already yielding new information about the nature of the dark universe."

Advanced LIGO's next data-taking run will begin this fall. By then, further improvements in detector sensitivity are expected to allow LIGO to reach as much as 1.5 to 2 times more of the volume of the universe. The Virgo detector is expected to join in the latter half of the upcoming observing run.

LIGO research is carried out by the LIGO Scientific Collaboration (LSC), a group of more than 1,000 scientists from universities around the United States and in 14 other countries. More than 90 universities and research institutes in the LSC develop detector technology and analyze data; approximately 250 students are strong contributing members of the collaboration. The LSC detector network includes the LIGO interferometers and the GEO600 detector.

Virgo research is carried out by the Virgo Collaboration, consisting of more than 250 physicists and engineers belonging to 19 different European research groups: 6 from Centre National de la Recherche Scientifique (CNRS) in France; 8 from the Istituto Nazionale di Fisica Nucleare (INFN) in Italy; 2 in The Netherlands with Nikhef; the MTA Wigner RCP in Hungary; the POLGRAW group in Poland and the European Gravitational Observatory (EGO), the laboratory hosting the Virgo detector near Pisa in Italy. [7]

Simulations suggest other phenomenon besides black holes merging could produce gravity waves

Researchers working on the LIGO project created a lot of excitement earlier this year when they announced that they had made the first ever detection of gravitational waves. Most in the field believe that such waves are, or were, the result of two black holes colliding. But, simulations created in this latest effort suggest that other sources are possible as well.

At issue are ringdowns, which are parts of the gravitational radiation that is emitted when a new but distorted black hole forms and takes shape after two other black holes have collided—as the waves decay a ringdown signal is emitted. But, other events can lead to ringdowns too, the researchers suggest, by so-called black-hole mimics—objects that are extremely compact, but do not have an event horizon—instead, they have light rings. In simulating and then comparing the ringdowns from such objects with those from black holes merging, the team found that under the right set of conditions, the two could be very nearly indistinguishable. But, they also report, as the ringdowns die out, the echoes they create take a long time to die, but as they do, the signal types eventually diverge, offering a means for identifying the original source.

Sadly, data from the LIGO project was not strong enough to show whether the ringdown die out resembled that of the simulated signal from a black hole collision or from some other object. But, going forward, as updates are made to equipment and future signals are detected, it should be possible, the team reports, to spot the differences, if the simulations are correct. [6]

Scientists glimpse Einstein's gravitational waves

When two black holes collided some 1.3 billion years ago, the joining of those two great masses sent forth a wobble that hurtled through space and arrived at Earth on September 14, 2015, when it was picked up by sophisticated instruments, researchers announced.

"Like Galileo first pointing his telescope upward, this new view of the sky will deepen our understanding of the cosmos, and lead to unexpected discoveries," said France Cordova, director of the US National Science Foundation, which funded the work.

The phenomenon was observed by two US-based underground detectors, designed to spot tiny vibrations from passing gravitational waves, a project known as the Laser Interferometer Gravitational-wave Observatory, or LIGO.

It took scientists months to verify their data and put it through a process of peer-review before announcing it on Thursday, marking the culmination of decades of efforts by teams around the world.

"LIGO has ushered in the birth of an entirely new field of astrophysics," said Cordova.

Gravitational waves are a measure of strain in space, an effect of the motion of large masses that stretches the fabric of space-time—a way of viewing space and time as a single, interweaved continuum.

They travel at the speed of light and cannot be stopped or blocked by anything.

Einstein said space-time could be compared to a net, bowing under the weight of an object. Gravitational waves would be like ripples that emanate from a pebble thrown in a pond.

While scientists have previously been able to calculate gravitational waves, they had never before seen one directly.

Wobbling like jelly

According to the Massachusetts Institute of Technology's (MIT) David Shoemaker, the leader of the LIGO team, it looked just like physicists thought it would.

"The waveform that we can calculate based on Einstein's theory of 1916 matches exactly what we observed in 2015," David Shoemaker, the leader of the LIGO team, told AFP.

"It looked like a chirp, it looked at something that started at low frequencies—for us low frequencies means 20 or 30 hertz, that's like the lowest note on a bass guitar, sweeping very rapidly up over just a fraction of a second... up to 150 hertz or so, sort of near middle C on a piano."

The chirp "corresponded to the orbit of these two black holes getting smaller and smaller, and the speed of the two objects going faster and faster until the two became a single object," he explained.

"And then right at the end of this waveform, we see the wobbling of the final black hole as if it were made of jelly as it settled into a static state."

Underground detectors

The L-shaped LIGO detectors—each about 1.5 kilometers (four kilometers) long—were conceived and built by researchers at MIT and Caltech.

One is located in Hanford, Washington, and the other is in Livingston, Louisiana.

A third detector, called VIRGO, is scheduled to open in Italy later this year.

Tuck Stebbins, head of the gravitational astrophysics laboratory at NASA's Goddard Spaceflight Center, described the detectors as the "most complex machines humans have ever built."

Both LIGO and VIRGO have undergone major upgrades in recent years.

Physicist Benoit Mours of France's National Center for Scientific Research (CNRS), which is leading the VIRGO team along with Italian colleagues, described the discovery as "historic" because it "allows us to directly verify one of the predictions of the theory of general relativity."

Physicists said the gravitational wave detected at 1651 GMT on September 14 originated in the last fraction of a second before the fusion of two black holes somewhere in the southern sky, though they can't say precisely where.

Einstein had predicted such a phenomenon would occur when two black holes collided, but it had never before been observed.

An analysis by the MIT and Caltech found that the two black holes joined about 1.3 billion years ago, and their mass was 29-36 times greater than the Sun.

The wave arrived first at the Louisiana detector, then at the Washington instrument 7.1 milliseconds later.

The two instruments are 1,800 miles (3,000 kilometers) apart, and since both made the same reading, scientists consider their discovery confirmed.

'New era '

"Black holes are interesting because they do not give off any light and that is why these particular objects had never been seen before—because all of the astrophysical instruments to date use light," said Shoemaker.

"So this is one of the ways in which this tool is special and unique in the astronomical toolkit."

He said the new data "can really help to explain the formation of galaxies and overall large scale structures of the material in the universe."

Details of the discovery are being published in the journal Physical Review Letters.

Indirect proof of gravitational waves was found in 1974 through the study of a pulsar and a neutron star. Scientists Russell Hulse and Joseph Taylor won the Nobel Prize for physics for that work in 1993.

"Humanity has now another tool for exploring the universe," Stebbins told AFP.

"This is like the perfect outcome. The door is open to new discoveries," he added.

"This is a new era in astrophysics." [5]

Probing Strange Stars with Advanced Gravitational Wave

The only known way to find strange matter at the moment would be to confirm its existence within neutron stars. On Earth, it is currently impossible to directly observe strange matter, even in places like the Large Hadron Collider at Cern in Switzerland. Pictured is the Large Hadron Collider Beauty experiment (LHCb).

'As its name says, a neutron star is a star made up of neutrons - which are made up of two down and one up quarks,' Dr Moraes continued.

'It is a star of very high density and rapid rotation rate. Most of them have masses close to 1.3-1.4 solar masses.'

Most matter we see comes in two 'flavours', made up of just two types of fundamental particles - up and down quarks.

WHAT IS A NEUTRON STAR?

When the core of a massive star undergoes gravitational collapse at the end of its life, protons and electrons are literally scrunched together, leaving behind one of nature's most wondrous creations: a neutron star.

Neutron stars cram roughly 1.3 to 2.5 solar masses into a city-sized sphere perhaps 12 miles (20 kilometers) across.

Matter is packed so tightly that a sugar-cube-sized amount of material would weigh more than 1 billion tons, about the same as Mount Everest.

But in these extreme conditions a rare type of three-flavour matter, made of up, down and strange quarks, could be being created.

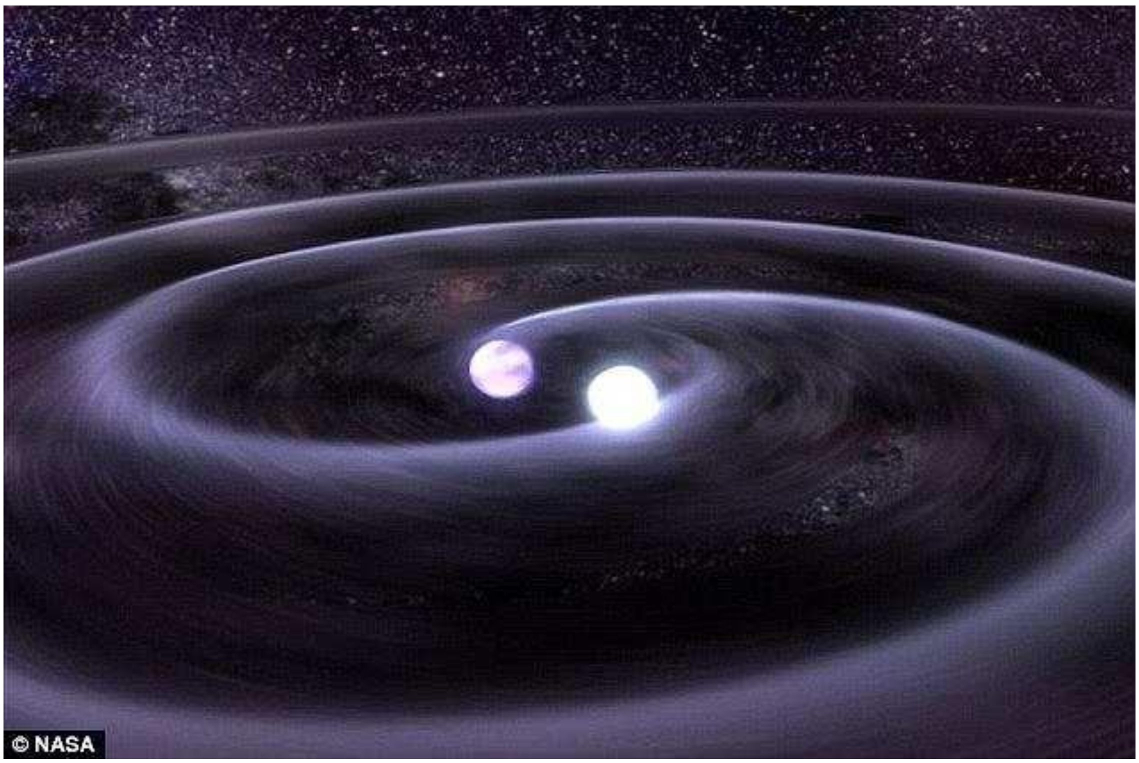
This is what strange matter would be. And Dr Moraes says, if the neutron star is massive enough and rotating at a fast enough speed, the entire star could be made of this matter.

The star would be much smaller and lighter than a neutron star. For example, a neutron star with a mass 0.2 times that of the sun would have a radius greater than nine miles (15km), but a strange star of the same mass would be less than a third the size.

One of the implications of the theory, if true, would be that there might be more types of matter in the universe than we know of.

Dr Moraes says, as we cannot observe individual fundamental particles like quarks on Earth, the only way to prove strange matter's existence would be to spot it in a neutron star.

Interestingly, though, proving that strange stars exist could also provide a detection for one of the 'holy grails' of astronomy - gravitational waves.



Dr Moraes says the interaction of a neutron star and a strange star (illustration shown) could create ripples in space-times, resulting in gravitational waves. These are one of the 'holy grails' of astronomy that have been impossible to detect in other experiments so far. [4]

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 = hν*** and ***E = mc²***, ***m = hν /c²*** 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.

If the mass is electromagnetic, then the gravitation is also electromagnetic effect caused by the accelerating Universe! The same charges would attract each other if they are moving parallel by the magnetic effect.

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]

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 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]

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.

In my opinion, the best explanation of the Higgs mechanism for a lay audience is the one invented by David Miller. You can find it here: http://www.strings.ph.qmul.ac.uk/~jmc/epp/higgs3.html .
The field must come first. The boson is an excitation of the field. So no field, no excitation. On the other hand in quantum field theory it is difficult to separate the field and the excitations. The Higgs field is what gives particles their mass.
There is a video that gives an idea as to the Higgs field and the boson. It is here: http://www.youtube.com/watch?v=RIg1Vh7uPyw . Note that this analogy isn't as good as the Miller one, but as is usually the case, if you look at all the analogies you'll get the best understanding of the situation.

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

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.

Conclusions

The latest theory was proposed by Dr Pedro Moraes and Dr Oswaldo Miranda, both of the National Institute for Space Research in Brazil. They say that some types of neutron stars might be made of a new type of matter called strange matter. What the properties of this matter would be, though, are unknown - but it would likely be a 'liquid' of several types of sub-atomic particles. [4]

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