History of Galaxies

Each galaxy has a fado—a narrative of its biography since the birth of its first stars. This fate is written in its electromagnetic spectrum, which contains the fossil records of multiple stellar populations that formed over several billion years, as well as the gas that those stars ionize with their radiation. [8]

The Earth is constantly jostled by low-frequency gravitational waves from supermassive black hole binaries in distant galaxies. Astrophysicists are using pulsars as a galaxy-sized detector to measure the Earth's motion from these waves. [7]

Last week's announcement that Gravitational Waves (GW) have been detected for the first time—as a result of the merger of two black holes—is huge news. But now a Gamma Ray Burst (GRB) originating from the same place, and that arrived at Earth 0.4 seconds after the GW, is making news. Isolated black holes aren't supposed to create GRB's; they need to be near a large amount of matter to do that. [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.

Contents

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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.

FADO—a ground-breaking tool to reconstruct the history of galaxies

FADO is a new analysis tool developed by Instituto de Astrofísica e Ciências do Espaço (IA) astronomers Jean Michel Gomes and Polychronis Papaderos, which uses light emitted by both stars and ionized gas in a galaxy to reconstruct its formation history by means of genetic algorithms. This tool was presented in a recent article, accepted for publication in the journal Astronomy & Astrophysics.

"Fado" derives from the Latin "Fatum," which means fate or destiny, and it's a tribute to Portugal's immaterial cultural heritage type of music of the same name. Each galaxy has a fado—a narrative of its biography since the birth of its first stars. This fate is written in its electromagnetic spectrum, which contains the fossil records of multiple stellar populations that formed over several billion years, as well as the gas that those stars ionize with their radiation.

Deciphering the star formation history of a galaxy from its spectrum is one of the most challenging tasks in astronomy. An innovative and distinctive feature of FADO is the use of genetic algorithms, which simulates galaxy evolution like the evolution of a living organism. It works by "breeding" multiple genetic threads for a galaxy, each defined by a set of parameters (similar to the genetic code in DNA), which evolve through exchange of "chromosomes," mutations and selection effects, until a population that matches the observed stars and gas emission of the galaxy is reached.

Jean Michel Gomes (IA & University of Porto) says, "FADO is the first spectral modeling code employing genetic differential evolution optimization in combination with artificial intelligence algorithms. This results in key improvements in computational efficiency and accuracy to which the star formation history of galaxies can be reconstructed."

Previous computer models developed for this purpose suffer from severe uncertainties, partly because they take into account only the light from stars. However, the contribution from ionized gas can add up to 50 percent of all emitted light in a galaxy.

Researcher Polychronis Papaderos says, "FADO is the first code of its type that simultaneously models stellar and ionized gas emissions in galaxies. It also integrates physical prescriptions which ensure that the star formation history computed for a galaxy consistently reproduces its observed ionized gas emission. This presently unique self-consistency concept, in conjunction with the innovative mathematical foundation of FADO will allow us to gain new sharp insights into the galaxy formation history."

FADO's unique physical and mathematical concept yields great gain in computational efficiency, making the exploration of the star formation history of millions of galaxies an affordable task.

FADO will be an essential analysis tool to use with new generation instruments like MOONS, to be installed in the VLT (ESO). "MOONS is being constructed under the co-coordination of IA, and includes a substantial scientific and technical contribution from the Portuguese team. FADO will enhance tremendously our capability of exploiting the state-of-the-art observations MOONS will do from 2019 onwards," states the coordinator of IA, José Afonso. [8]

Gravitational wave search provides insights into galaxy evolution and mergers

New results from NANOGrav - the North American Nanohertz Observatory for Gravitational Waves - establish astrophysically significant limits in the search for low-frequency gravitational waves. This result provides insight into how often galaxies merge, and how those merging galaxies evolve over time. To obtain this result, scientists required an exquisitely precise, nine-year pulsar-monitoring campaign conducted by two of the most sensitive radio telescopes on Earth, the Green Bank Telescope in West Virginia and the Arecibo Observatory in Puerto Rico.

The recent LIGO detection of gravitational waves from merging black holes with tens of solar masses has confirmed that distortions in the fabric of space-time can be observed and measured. Researchers from the North American Nanohertz Observatory for Gravitational Waves (NANOGrav) have spent the past decade searching for low-frequency gravitational waves emitted by black hole binaries with masses many millions of times larger than those seen by LIGO.

Analysis of NANOGrav's nine-year dataset provides very constraining limits on the prevalence of such supermassive black hole binaries throughout the Universe.

Given scientists' current understanding of how often galaxies merge, these limits point to fewer detectable supermassive black hole binaries than were previously expected. This result has significant impacts on our understanding of how galaxies and their central black holes co-evolve.

Low-frequency gravitational waves are very difficult to detect, with wavelengths spanning light-years, and originating from black hole binaries in galaxies spread across the sky. The combination of all these giant binary black holes leads to a constant "hum" of gravitational waves that models predict should be detectable at Earth. Astrophysicists call this effect the "stochastic gravitational wave background," and detecting it requires special analysis techniques.

Pulsars are the cores of massive stars left behind after stars go supernova and emit pulses of radio waves as they spin. The fastest pulsars rotate hundreds of times each second and emit a pulse every few milliseconds. These "millisecond pulsars" (MSPs) are considered nature's most precise clocks and are ideal for detecting the small signal from gravitational waves. "This measurement is possible because the gravitational wave background imprints a unique signature onto the radio waves seen from a collection of MSPs," said Justin Ellis, Einstein Fellow at NASA's Jet Propulsion Laboratory, California Institute of Technology in Pasadena, California, and a co-author on the report published yesterday in Astrophysical Journal.

Astrophysicists use computer models to predict how often galaxies merge and form supermassive black hole binaries. Those models use several simplifying assumptions about how black hole binaries evolve when they predict the strength of the stochastic gravitational wave background. By using information about galaxy mergers and constraints on the background, the scientists are able to improve their assumptions about black hole binary evolution.

Ellis continues, "After nine years of observing a collection of MSPs, we haven't detected the stochastic background but we are beginning to rule out many predictions based on current models of galaxy evolution. We are now at a point where the non-detection of gravitational waves is actually improving our understanding of black hole binary evolution."

"Pulsar timing arrays like NANOGrav are making novel observations of the evolution and nature of our Universe," says Sarah Burke Spolaor, Jansky Fellow at the National Radio Astronomy Observatory (NRAO) in Soccoro, New Mexico, and a co-author on the paper.

According to Spolaor, there are two possible interpretations of this non-detection. "Some supermassive black hole binaries may not be in circular orbits or are significantly interacting with gas or stars. This would drive them to merge faster than simple models have assumed in the past." An alternate explanation is that many of these binaries inspiral too slowly to ever emit detectable gravitational waves.

NANOGrav is currently monitoring 54 pulsars, using the National Science Foundation's Green Bank Telescope in West Virginia and Arecibo Radio Observatory in Puerto Rico, the two most sensitive radio telescopes at these frequencies. Their array of pulsars is continually growing as new MSPs are discovered. In addition,

the group collaborates with radio astronomers in Europe and Australia as part of the International Pulsar Timing Array, giving them access to many more pulsar observations. Ellis estimates that this increase in sensitivity could lead to a detection in as little as five years.

In addition, this measurement helps constrain the properties of cosmic strings, very dense and thin cosmological objects, which many theorists believe evolved when the Universe was just a fraction of a second old. These strings can form loops, which then decay through gravitational wave emission. The most conservative NANOGrav limit on cosmic string tension is the most stringent limit to date, and will continue to improve as NANOGrav continues operating.

"These new results from NANOGrav have the most important astrophysical implications yet," said Scott Ransom, an astronomer with NRAO in Charlottesville, Virginia. "As we improve our detection capabilities, we get closer and closer to that important threshold where the cosmic murmur begins to be heard. At that point, we'll be able to perform entirely new types of physics experiments on cosmic scales and open up a new window on the Universe, just like LIGO just did for high-frequency gravitational waves."

NANOGrav is a collaboration of over 60 scientists at over a dozen institutions in the United States and Canada whose goal is detecting low-frequency gravitational waves to open a new window on the Universe. The group uses radio pulsar timing observations to search for the ripples in the fabric of spacetime.

In 2015, NANOGrav was awarded $14.5 million by the National Science Foundation to create and operate a Physics Frontiers Center. "The Physics Frontier Centers bring people together to address frontier science, and NANOGrav's work in low-frequency gravitational wave physics is a great example," said Jean Cottam Allen, the NSF program director who oversees the Physics Frontiers Center program. "We're delighted with their progress thus far, and we're excited to see where it will lead." [7]

Did a gamma ray burst accompany LIGO's gravity wave detection?

NASA's Fermi telescope detected the GRB, coming from the same point as the GW, a mere 0.4 seconds after the waves arrived. Though we can't be absolutely certain that the two phenomena are from the same black hole merger, the Fermi team calculates the odds of that being a coincidence at only 0.0022%. That's a pretty solid correlation.

So what's going on here? To back up a little, let's look at what we thought was happening when LIGO detected gravitational waves.

Our understanding was that the two black holes orbited each other for a long time. As they did so, their massive gravity would have cleared the area around them of matter. By they time they finished circling each other and merged, they would have been isolated in space. But now that a GRB has been detected, we need some way to account for it. We need more matter to be present.

According to Abraham Loeb, of Harvard University, the missing piece of this puzzle is a massive star—itself the result of a binary star system combining into one—a few hundred times larger than the Sun, that spawned two black holes. A star this size would form a black hole when it exhausted its fuel and collapsed. But why would there be two black holes?

Again, according to Loeb, if the star was rotating at a high enough rate—just below its break up frequency—the star could actually form two collapsing cores in a dumbbell configuration, and hence two black holes. But now these two black holes would not be isolated in space, they would actually be inside a massive star. Or what was left of one. The remnants of the massive star is the missing matter.

When the black holes joined together, an outflow would be generated, which would produce the GRB. Or else the GRB came "from a jet originating out of the accretion disk of residual debris around the BH remnant," according to Loeb's paper. So why the 0.4 s delay? This is the time it took the GRB to cross the star, relative to the gravitational waves.

It sounds like a nice tidy explanation. But, as Loeb notes, there are some problems with it. The main question is, why was the GRB so weak, or dim? Loeb's paper says that "observed GRB may be just one spike in a longer and weaker transient below the GBM detection threshold."

But was the GRB really weak? Or was it even real? The European Space Agency has their own gamma ray detecting spacecraft, called Integral. Integral was not able to confirm the GRB signal, and according to this paper, the gamma ray signal was not real after all. [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.

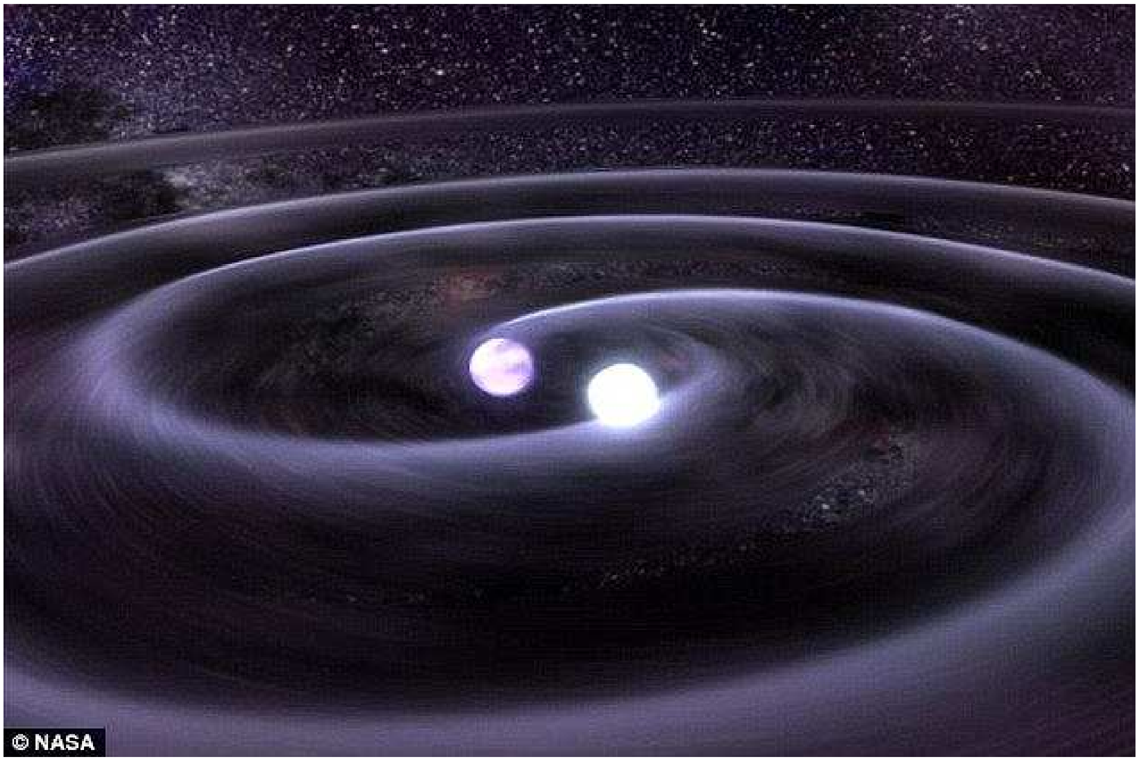
This is what strange matter would be. And Dr Moraes says, if the neutron star is massive enough and rotating at a fast enough speed, the entire star could be made of this matter.

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

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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