

How a Fuzzy Universe Looked

Shortly after the Big Bang, particles of dark matter would have clumped together in gravitational "halos," pulling surrounding gas into their cores, which over time cooled and condensed into the first galaxies. [21]

Scientists are hoping to understand one of the most enduring mysteries in cosmology by simulating its effect on the clustering of galaxies. [20]

The U.S. Department of Energy has approved nearly \$1 million in funding for the research team, which has been tasked with leveraging large-scale computer simulations and developing new statistical methods to help us better understand these fundamental forces. [19]

According to a new study, they could also potentially detect dark matter, if dark matter is composed of a particular kind of particle called a "dark photon." [18]

A global team of scientists, including two University of Mississippi physicists, has found that the same instruments used in the historic discovery of gravitational waves caused by colliding black holes could help unlock the secrets of dark matter, a mysterious and as-yet-unobserved component of the universe. [17]

The lack of so-called "dark photons" in electron-positron collision data rules out scenarios in which these hypothetical particles explain the muon's magnetic moment. [16]

By reproducing the complexity of the cosmos through unprecedented simulations, a new study highlights the importance of the possible behaviour of very high-energy photons. In their journey through intergalactic magnetic fields, such photons could be transformed into axions and thus avoid being absorbed. [15]

Scientists have detected a mysterious X-ray signal that could be caused by dark matter streaming out of our Sun's core.

Hidden photons are predicted in some extensions of the Standard Model of particle physics, and unlike WIMPs they would interact electromagnetically with normal matter.

In particle physics and astrophysics, weakly interacting massive particles, or WIMPs, are among the leading hypothetical particle physics candidates for dark matter.

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.

Contents

The Big Bang.....	3
This is how a 'fuzzy' universe may have looked	4
Fuzzy waves	4
A map of harp strings	6
Dark matter clusters could reveal nature of dark energy.....	7
Gravitational lensing	7
Fifth force.....	7
Pushing the limits.....	8
Large-scale simulations could shed light on the 'dark' elements that make up most of our cosmos	8
Gravitational wave detectors to search for dark matter	9
Gravitational wave detectors could shed light on dark matter	10
Synopsis: Dark Photon Conjecture Fizzles.....	12
Exchanges of identity in deep space	12
Astronomers may have detected the first direct evidence of dark matter	13
Hidden photons	15
Ideal mirror at hand.....	15
Dark matter composition research - WIMP	15
Weakly interacting massive particles	16
Evidence for an accelerating universe.....	16
Equation.....	17
Explanatory models	18
Dark Matter and Energy	18
Cosmic microwave background	18

Thermal radiation.....	18
Electromagnetic Field and Quantum Theory	19
Lorentz transformation of the Special Relativity	20
The Classical Relativistic effect.....	20
Electromagnetic inertia and Gravitational attraction	20
Electromagnetic inertia and mass.....	21
Electromagnetic Induction	21
Relativistic change of mass	21
The frequency dependence of mass.....	21
Electron – Proton mass rate	21
Gravity from the point of view of quantum physics	22
The Gravitational force	22
The Graviton	22
Conclusions.....	22
References	23

Author: George Rajna

The Big Bang

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.

This is how a 'fuzzy' universe may have looked

Dark matter was likely the starting ingredient for brewing up the very first galaxies in the universe. Shortly after the Big Bang, particles of dark matter would have clumped together in gravitational "halos," pulling surrounding gas into their cores, which over time cooled and condensed into the first galaxies.

Although dark matter is considered the backbone to the structure of the universe, scientists know very little about its nature, as the particles have so far evaded detection.

Now scientists at MIT, Princeton University, and Cambridge University have found that the early universe, and the very first galaxies, would have looked very different depending on the nature of dark matter. For the first time, the team has simulated what early galaxy formation would have looked like if dark matter were "fuzzy," rather than cold or warm.

In the most widely accepted scenario, dark matter is cold, made up of slow-moving particles that, aside from gravitational effects, have no interaction with ordinary matter. Warm dark matter is thought to be a slightly lighter and faster version of cold dark matter. And fuzzy dark matter, a relatively new concept, is something entirely different, consisting of ultralight particles, each about 1 octillionth (10^{-27}) the mass of an electron (a cold dark matter particle is far heavier—about 105 times more massive than an electron).

In their simulations, the researchers found that if dark matter is cold, then galaxies in the early universe would have formed in nearly spherical halos. But if the nature of dark matter is fuzzy or warm, the early universe would have looked very different, with galaxies forming first in extended, tail-like filaments. In a fuzzy universe, these filaments would have appeared striated, like star-lit strings on a harp.

As new telescopes come online, with the ability to see further back into the early universe, scientists may be able to deduce, from the pattern of galaxy formation, whether the nature of dark matter, which today makes up nearly 85 percent of the matter in the universe, is fuzzy as opposed to cold or warm.

"The first galaxies in the early universe may illuminate what type of dark matter we have today," says Mark Vogelsberger, associate professor of physics in MIT's Kavli Institute for Astrophysics and Space Research. "Either we see this filament pattern, and fuzzy dark matter is plausible, or we don't, and we can rule that model out. We now have a blueprint for how to do this."

Vogelsberger is a co-author of a paper appearing in *Physical Review Letters*, along with the paper's lead author, Philip Mocz of Princeton University, and Anastasia Fialkov of Cambridge University and previously the University of Sussex.

Fuzzy waves

While dark matter has yet to be directly detected, the hypothesis that describes dark matter as cold has proven successful at describing the large-scale structure of the observable universe. As a result, models of galaxy formation are based on the assumption that dark matter is cold.

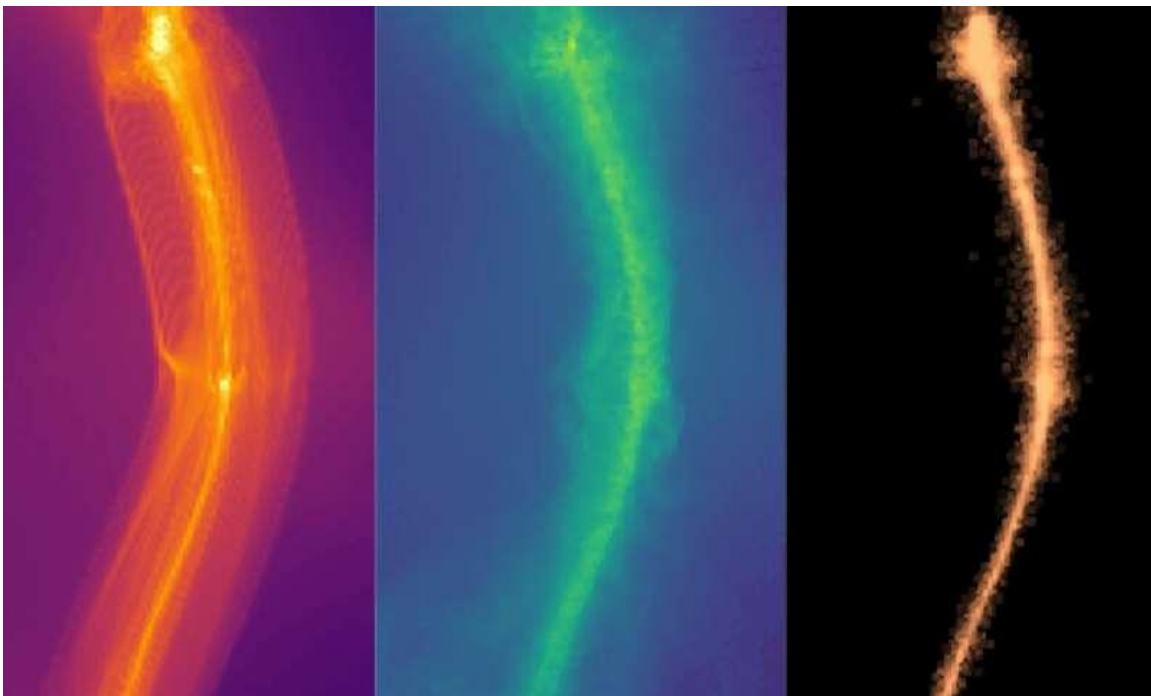
"The problem is, there are some discrepancies between observations and predictions of cold dark matter," Vogelsberger points out. "For example, if you look at very small galaxies, the inferred

distribution of dark matter within these galaxies doesn't perfectly agree with what theoretical models predict. So there is tension there."

Enter, then, alternative theories for dark matter, including warm, and fuzzy, which researchers have proposed in recent years.

"The nature of dark matter is still a mystery," Fialkov says. "Fuzzy dark matter is motivated by fundamental physics, for instance, string theory, and thus is an interesting dark matter candidate. Cosmic structures hold the key to validating or ruling out such dark matter models."

Fuzzy dark matter is made up of particles that are so light that they act in a quantum, wave-like fashion, rather than as individual particles. This quantum, fuzzy nature, Mocz says, could have produced early galaxies that look entirely different from what standard models predict for cold dark matter.



Simulations of how the filament (tail) of a galaxy forms in cold, warm and fuzzy (left to right) dark matter scenarios. Credit: Universities of Princeton, Cambridge and Sussex

"Even though in the late universe these different dark matter scenarios may predict similar shapes for galaxies, the first galaxies would be strikingly different, which will give us a clue about what dark matter is," Mocz says.

To see how different a cold and a fuzzy early universe could be, the researchers simulated a small, cubic space of the early universe, measuring about 3 million light years across, and ran it forward in time to see how galaxies would form given one of the three dark matter scenarios: cold, warm, and fuzzy.

The team began each simulation by assuming a certain distribution of dark matter, which scientists have some idea of, based on measurements of the cosmic microwave background—"relic radiation" that was emitted by, and was detected just 400,000 years after, the Big Bang.

"Dark matter doesn't have a constant density, even at these early times," Vogelsberger says. "There are tiny perturbations on top of a constant density field."

The researchers were able to use existing algorithms to simulate galaxy formation under scenarios of cold and warm dark matter. But to simulate fuzzy dark matter, with its quantum nature, they needed a new approach.

A map of harp strings

The researchers modified their simulation of cold dark matter, enabling it to solve two extra equations in order to simulate galaxy formation in a fuzzy dark matter universe. The first, Schrödinger's equation, describes how a quantum particle acts as a wave, while the second, Poisson's equation, describes how that wave generates a density field, or distribution of dark matter, and how that distribution leads to gravity—the force that eventually pulls in matter to form galaxies. They then coupled this simulation to a model that describes the behavior of gas in the universe, and the way it condenses into galaxies in response to gravitational effects.

In all three scenarios, galaxies formed wherever there were over-densities, or large concentrations of gravitationally collapsed dark matter. The pattern of this dark matter, however, was different, depending on whether it was cold, warm, or fuzzy.

In a scenario of cold dark matter, galaxies formed in spherical halos, as well as smaller subhalos. Warm dark matter produced first galaxies in tail-like filaments, and no subhalos. This may be due to warm dark matter's lighter, faster nature, making particles less likely to stick around in smaller, subhalo clumps.

Similar to warm dark matter, fuzzy dark matter formed stars along filaments. But then quantum wave effects took over in shaping the galaxies, which formed more striated filaments, like strings on an invisible harp. Vogelsberger says this striated pattern is due to interference, an effect that occurs when two waves overlap. When this occurs, for instance in waves of light, the points where the crests and troughs of each wave align form darker spots, creating an alternating pattern of bright and dark regions.

In the case of fuzzy dark matter, instead of bright and dark points, it generates an alternating pattern of over-dense and under-dense concentrations of dark matter.

"You would get a lot of gravitational pull at these over-densities, and the gas would follow, and at some point would form galaxies along those over-densities, and not the under-densities," Vogelsberger explains. "This picture would be replicated throughout the early universe."

The team is developing more detailed predictions of what early galaxies may have looked like in a universe dominated by fuzzy dark matter. Their goal is to provide a map for upcoming telescopes, such as the James Webb Space Telescope, that may be able to look far enough back in time to spot the earliest galaxies. If they see filamentary galaxies such as those simulated by Mocz, Fialkov, Vogelsberger, and their colleagues, it could be the first signs that dark matter's nature is fuzzy.

"It's this observational test we can provide for the nature of dark matter, based on observations of the early universe, which will become feasible in the next couple of years," Vogelsberger says. [21]

Dark matter clusters could reveal nature of dark energy

Scientists are hoping to understand one of the most enduring mysteries in cosmology by simulating its effect on the clustering of galaxies.

That mystery is dark energy – the phenomenon that scientists hypothesise is causing the universe to expand at an ever-faster rate. No-one knows anything about dark energy, except that it could be, somehow, blowing pretty much everything apart.

Meanwhile, dark energy has an equally shady cousin – dark matter. This invisible substance appears to have been clustering around galaxies, and preventing them from spinning themselves apart, by lending them an extra gravitational pull.

Such a clustering effect is in competition with dark energy's accelerating expansion. Yet studying the precise nature of this competition might shed some light on dark energy.

"Many dark energy models are already ruled out with current data," said Dr. Alexander Mead, a cosmologist at the University of British Columbia in Vancouver, Canada, who is working on a project called Halo modelling. "Hopefully in future we can rule more out."

Gravitational lensing

Currently, the only way dark matter can be observed is by looking for the effects of its gravitational pull on other matter and light. The intense gravitational field it produces can cause light to distort and bend over large distances – an effect known as gravitational lensing.

By mapping the dark matter in distant parts of the cosmos, scientists can work out how much dark matter clustering there is – and in principle how that clustering is being affected by dark energy.

The link between gravitational lensing and dark matter clustering is not straightforward, however. To interpret the data from telescopes, scientists must refer to detailed cosmological models – mathematical representations of complex systems.

Dr. Mead is developing a clustering model that he hopes will have enough accuracy to distinguish between different dark-energy hypotheses.

"An analogy I like a lot is with turbulence. In turbulent fluid flow you can talk about currents and eddies, which are nice words, but the reality of how fluid in a pipe goes from flowing calmly to flowing in a turbulent fashion is extremely complicated."

Fifth force

One of the more exotic theories is that dark energy is the result of a hitherto undetected fifth force, in addition to nature's four known forces—gravity, electromagnetism, and the strong and weak nuclear forces inside atoms.

A more common hypothesis for dark energy, however, is known as the cosmological constant, which was put forward by Albert Einstein as part of his general theory of relativity. It is often believed to describe an all-pervading sea of virtual particles that are continually popping into and out of existence throughout the universe.

One way to rule out the cosmological constant hypothesis, of course, is to prove that dark energy is not constant at all. This is the goal of Dr. Pier Stefano Corasaniti of the Paris Observatory in France, who – in a project called EDECS – is approaching dark-matter clustering from a different direction.

Instead of attempting to model clustering from [gravitational lensing](#) data, he is beginning specifically with a dynamical – that is, not constant – hypothesis of dark energy, and trying to predict how dark matter would cluster if this was the case.

Pushing the limits

There are, in principle, infinite ways dark energy can vary in space and time, although many theories have already been ruled out by existing observations. Dr. Corasaniti is focussing his simulations on types of dynamical dark energy that push at the edges of these observational limits, paving the way for tests with future experiments.

The simulations, which trace the evolution of numerous, 'N-body' dark matter particles, require supercomputers running for long periods of time, processing several petabytes (one thousand million million bytes) of data.

"We have run among the largest cosmological N-body simulations ever realised," Dr. Corasaniti said.

Dr. Corasaniti's simulations predict that the way dark energy evolves over time ought to affect [dark matter](#) clustering. This, in turn, alters the efficiency with which galaxies form in ways that would not be the case with constant dark energy.

The predictions his models are making could be tested with the help of forthcoming telescopes such as the Large Synoptic Survey Telescope in Chile and the Square Kilometre Array in Australia and South Africa, as well as by satellite missions such as Euclid (EUropean Cooperation for LighTning Detection) and WFIRST (Wide Field Infrared Survey Telescope).

"If [dark energy](#) turns out to be a dynamical phenomenon this will have a profound implication not only on cosmology, but on our understanding of fundamental physics," said Dr. Corasaniti. [20]

Large-scale simulations could shed light on the 'dark' elements that make up most of our cosmos

If you only account for the matter we can see, our entire galaxy shouldn't exist. The combined gravitational pull of every known moon, planet, and star should not have been strong enough to produce a system as dense and complex as the Milky Way.

So what's held it all together?

Scientists believe there is a large amount of additional matter in the universe that we can't observe directly – so-called "[dark matter](#)." While it is not known what dark matter is made of, its effects on light and gravity are apparent in the very structure of our galaxy. This, combined with the even more mysterious "[dark energy](#)" thought to be speeding up the universe's expansion, could make up as much as 96 percent of the entire cosmos.

In an ambitious effort directed by Argonne National Laboratory, researchers at the Biocomplexity Institute of Virginia Tech are now attempting to estimate key features of the universe, including its relative distributions of dark matter and dark energy. The U.S. Department of Energy has approved nearly \$1 million in funding for the research team, which has been tasked with leveraging large-scale computer simulations and developing new statistical methods to help us better understand these fundamental forces.

To capture the impact of dark matter and dark energy on current and future scientific observations, the research team plans to build on some of the powerful predictive technologies that have been employed by the Biocomplexity Institute to forecast the global spread of diseases like Zika and Ebola. Using observational data from sources like the Dark Energy Survey, scientists will attempt to better understand how these "dark" elements have influenced the evolution of the universe.

"It sounds somewhat incredible, but we've done similar things in the past by combining statistical methods with supercomputer simulations, looking at epidemics," said Dave Higdon, a professor in the Biocomplexity Institute's Social and Decision Analytics Laboratory and a faculty member in the Department of Statistics, part of the Virginia Tech College of Science.

"Using [statistical methods](#) to combine input data on population, movement patterns, and the surrounding terrain with detailed simulations can forecast how health conditions in an area will evolve quite reliably—it will be an interesting test to see how well these same principles perform on a cosmic scale."

If this effort is successful, results will benefit upcoming cosmological surveys and may shed light on a number of mysteries regarding the makeup and evolution of dark matter and dark energy. What's more, by reverse engineering the evolution of these elements, they could provide unique insights into more than 14 billion years of cosmic history. [19]

Gravitational wave detectors to search for dark matter

Gravitational wave detectors might be able to detect much more than gravitational waves. According to a new study, they could also potentially detect dark matter, if dark matter is composed of a particular kind of particle called a "dark photon." In the future, LIGO (Laser Interferometer Gravitational Wave Observatory) scientists plan to implement a search for dark photons, which will include certain previously unexplored regions of the dark photon parameter space.

A team of physicists, Aaron Pierce, Keith Riles, and Yue Zhao from the University of Michigan, have reported their proposal for using gravitational wave detectors to search for dark matter in a recent paper published in *Physical Review Letters*.

"This proposal nicely bridges the newly born field of gravitational wave astronomy with that of particle physics," Zhao told *Phys.org*. "Without any modifications, a [gravitational wave detector](#) can be used as a very sensitive direct dark matter [detector](#), with the potential for a five-sigma discovery of dark matter."

As the physicists explain in their paper, if dark photons have a very light mass, then they can be considered to behave like an oscillating background field, with the oscillation frequency determined by their mass. Gravitational wave detectors could potentially detect these oscillations because the oscillations may affect test objects placed in the gravitational wave detectors. For example, if two test objects located at different positions in the detector experience different displacements, this difference may be due to the relative phase of the [dark photon](#) field's oscillations at these different positions.

The physicists expect that both present Earth-based gravitational wave detectors such as LIGO, as well as future space-based gravitational wave detectors such as LISA (Laser Interferometer Space Antenna), will have the ability to search for dark [photon](#) dark matter. Using more than one detector would allow for cross-checking and better sensitivity.

In the future, the scientists plan to work on further developing the new [dark matter](#) search method and determining exactly what kind of signal a gravitational wave detector would receive if a dark photon were nearby.

"We plan to push this work well beyond a theoretical proposal," Zhao said. "First, we plan to carry out the data analysis using a simplified signal model and a straightforward search algorithm. Then we will gradually refine our search method and include a detailed simulation of the signal and detector response." [18]

Gravitational wave detectors could shed light on dark matter

A global team of scientists, including two University of Mississippi physicists, has found that the same instruments used in the historic discovery of gravitational waves caused by colliding black holes could help unlock the secrets of dark matter, a mysterious and as-yet-unobserved component of the universe.

The research findings by Emanuele Berti, UM associate professor of physics and astronomy, Shrobana Ghosh, a graduate student, and their colleagues appears in the September issue of *Physical Review Letters*, one of the most prestigious peer-reviewed academic journals in the field. "Stochastic and resolvable gravitational waves from ultralight bosons" is co-authored by fellow scientists Richard Brito, Enrico Barausse, Vitor Cardoso, Irina Dvorkin, Antoine Klein and Paolo Pani.

The nature of dark matter remains unknown, but scientists estimate that it is five times as abundant as ordinary matter throughout the universe.

"The nature of dark matter is one of the greatest mysteries in physics," Berti said. "It is remarkable that we can now do particle physics – investigate the "very small" – by looking at gravitational-wave emission from black holes, the largest and simplest objects in the universe."

PRL is one of several publications produced by the American Physical Society and American Institute of Physics. It contains papers considered to represent significant advances in research, and therefore, published quickly in short, letter format for a broad audience of physicists.

This paper details calculations by the scientists, who work in Germany, France, Italy, Portugal and the U.S., show that gravitational-wave interferometers can be used to indirectly detect the presence of dark matter.

A companion paper by the team, "Gravitational wave searches for ultralight bosons with LIGO and LISA," also has been accepted and will appear in Physical Review D.

Calculations show that certain types of dark matter could form giant clouds around astrophysical black holes. If ultralight scalar particles exist in nature, fast-spinning black holes would trigger the growth of such scalar "condensates" at the expense of their rotational energy, producing a cloud that rotates around the black hole, now more slowly-spinning, and emits gravitational waves, pretty much like a giant lighthouse in the sky.

"One possibility is that dark matter consists of scalar fields similar to the Higgs boson, but much lighter than neutrinos," Pani said. "This type of dark matter is hard to study in particle accelerators, such as the Large Hadron Collider at CERN, but it may be accessible to gravitational-wave detectors."

The team led by Brito studied gravitational waves emitted by the "black hole plus cloud" system. Depending on the mass of the hypothetical particles, the signal is strong enough to be detected by the Laser Interferometer Gravitational-wave Observatory, with instruments in Louisiana and Washington, and its European counterpart Virgo, as well as by the future space mission Laser Interferometer Space Antenna.

"Surprisingly, gravitational waves from sources that are too weak to be individually detectable can produce a strong stochastic background," Brito said. "This work suggests that a careful analysis of the background in LIGO data may rule out – or detect – ultralight dark matter by gravitational-wave interferometers."

"This is a new, exciting frontier in astroparticle physics that could shed light on our understanding of the microscopic universe."

LIGO has been offline for a few months for upgrades. The team plans to announce new, exciting results from its second observing run soon.

"Our work shows that careful analysis of stochastic gravitational waves in the data they have already taken may be used to place interesting constraints on the nature of dark matter," Berti said.

This innovative work "confirms the high quality of the work in astroparticle physics and gravitationalwave astronomy done by members of the gravitational physics group at UM, widely recognized as one of the leaders in the field," said Luca Bombelli, chair and professor of physics and astronomy at Ole Miss. [17]

Synopsis: Dark Photon Conjecture Fizzles

The lack of so-called "dark photons" in electron-positron collision data rules out scenarios in which these hypothetical particles explain the muon's magnetic moment.

Dark photons sound like objects confused about their purpose, but in reality they are part of a comprehensive theory of dark matter. Researchers imagine that dark photons have photon-like interactions with other dark matter particles. And these hypothetical particles have recently gained interest because they might explain why the observed value of the muon's anomalous magnetic moment disagrees slightly with predictions. However, this muon connection now appears to have been ruled out by the BaBar Collaboration at the SLAC National Accelerator Laboratory in California. The researchers found no signal of dark photons in their electron-positron collision data.

Like the normal photon, the dark photon would carry an electromagnetic-like force between dark matter particles. It could also potentially have a weak coupling to normal matter, implying that dark photons could be produced in high-energy collisions. Previous searches have failed to find a signature, but they have generally assumed that dark photons decay into electrons or some other type of visible particle.

For their new search, the BaBar Collaboration considered a scenario in which a dark photon is created with a normal photon in an electron-positron collision and then decays into invisible particles, such as other dark matter particles. In this case, only one particle—the normal photon—would be detected, and it would carry less than the full energy from the collision. Such missingenergy events can occur in other ways, so the team looked for a "bump" or increase in events at a specific energy that would correspond to the mass of the dark photon. They found no such bump up to masses of 8 GeV. The null result conflicts with models in which a dark photon contribution brings the predicted muon magnetic moment in line with observations. [16]

Exchanges of identity in deep space

By reproducing the complexity of the cosmos through unprecedented simulations, a new study highlights the importance of the possible behaviour of very high-energy photons. In their journey through intergalactic magnetic fields, such photons could be transformed into axions and thus avoid being absorbed.

Like in a nail-biting thriller full of escapes and subterfuge, photons from far-off light sources such as blazars could experience a continuous exchange of identity in their journey through the universe. This would allow these very tiny particles to escape an enemy which, if encountered, would annihilate them. Normally, very high-energy photons (gamma rays) should "collide" with the background light emitted by galaxies and transform into pairs of matter and antimatter particles, as envisaged by the Theory of Relativity. For this reason, the sources of very high-energy gamma rays should appear significantly less bright than what is observed in many cases.

A possible explanation for this surprising anomaly is that light photons are transformed into hypothetical weakly interacting particles, "axions," which, in turn, would change into photons, all due to the interaction with magnetic fields. A part of the photons would escape interaction with the intergalactic background light that would make them disappear. The importance of this process is emphasised by a study published in Physical Review Letters, which recreated an extremely refined model of the cosmic web, a network of filaments composed of gas and dark matter present throughout the universe, and of its magnetic fields. These effects are now awaiting comparison with those obtained experimentally through Cherenkov Telescope Array new generation telescopes.

Through complex and unprecedented computer simulations made at the CSCS Supercomputing Centre in Lugano, scholars have reproduced the so-called cosmic web and its associated magnetic fields to investigate the theory that photons from a light source are transformed into axions, hypothetical elementary particles, on interacting with an extragalactic magnetic field. Axions could then be changed back into photons by interacting with other magnetic fields. Researchers Daniele Montanino, Franco Vazza, Alessandro Mirizzi and Matteo Viel write, "Photons from luminous bodies disappear when they encounter extragalactic background light (EBL). But if on their journey they head into these transformations as envisaged by these theories, it would explain why, in addition to giving very important information on processes that occur in the universe, distant celestial bodies are brighter than expected from an observation on Earth. These changes would, in fact, enable a greater number of photons to reach the Earth."

Thanks to the wealth of magnetic fields present in the cosmic web's filaments, which were recreated with the simulations, the conversion phenomenon would seem much more relevant than predicted by previous models: "Our simulations reproduce a very realistic picture of the cosmos' structure. From what we have observed, the distribution of the cosmic web envisaged by us would markedly increase the probability of these transformations." The next step in the research is to compare simulation results with the experimental data obtained through the use of the Cherenkov Telescope Array Observatories detectors, the new-generation astronomical observatories, one of which is positioned in the Canary Islands and the other in Chile. They will study the universe through very high-energy gamma rays. [15]

Astronomers may have detected the first direct evidence of dark matter

Scientists have detected a mysterious X-ray signal that could be caused by dark matter streaming out of our Sun's core.

Now scientists at the University of Leicester have identified a signal on the X-ray spectrum which appears to be a signature of 'axions' - a hypothetical dark matter particle that's never been detected before.

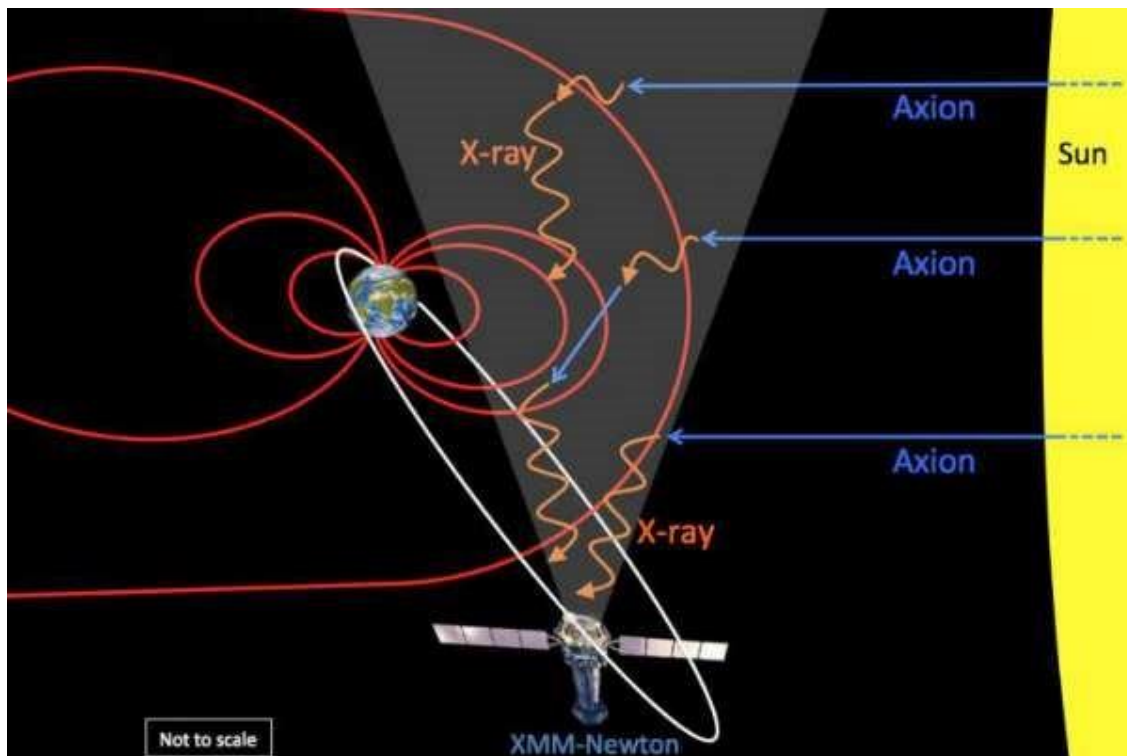
While we can't get too excited just yet - it will take years to confirm whether this signal really is dark matter - the discovery would completely change our understanding of how the Universe works. After all, dark matter is the force that holds our galaxies together, so learning more about it is pretty important.

The researchers first detected the signal while searching through 15 years of measurements taking by the European Space Agency's orbiting XMM-Newton space observatory.

Unexpectedly, they noticed that the intensity of X-rays recorded by the spacecraft rose by about 10% whenever XMM-Newton was at the boundary of Earth's magnetic field facing the Sun - even once they removed all the bright X-ray sources from the sky. Usually, that X-ray background is stable. "The X-ray background - the sky, after the bright X-ray sources are removed - appears to be unchanged whenever you look at it," said Andy Read, from the University of Leicester, one of the lead authors on the paper, in a press release. "However, we have discovered a seasonal signal in this X-ray background, which has no conventional explanation, but is consistent with the discovery of axions."

Researchers predict that axions, if they exist, would be produced invisibly by the Sun, but would convert to X-rays as they hit Earth's magnetic field. This X-ray signal should in theory be strongest when looking through the sunward side of the magnetic field, as this is where the Earth's magnetic field is strongest.

The next step is for the researchers to get a larger dataset from XMM-Newton and confirm the pattern they've seen in X-rays. Once they've done that, they can begin the long process of proving that they have, in fact, detecting dark matter streaming out of our Sun's core.



A sketch (not to scale) shows axions (blue) streaming out of the Sun and then converting into X-rays (orange) in the Earth's magnetic field (red). The X-rays are then detected by the XMM-Newton observatory. [13]

The axion is a hypothetical elementary particle postulated by the Peccei–Quinn theory in 1977 to resolve the strong CP problem in quantum chromodynamics (QCD). If axions exist and have low mass within a specific range, they are of interest as a possible component of cold dark matter. [14]

Hidden photons

Hidden photons are predicted in some extensions of the Standard Model of particle physics, and unlike WIMPs they would interact electromagnetically with normal matter. Hidden photons also have a very small mass, and are expected to oscillate into normal photons in a process similar to neutrino oscillation. Observing such oscillations relies on detectors that are sensitive to extremely small electromagnetic signals, and a number of these extremely difficult experiments have been built or proposed.

A spherical mirror is ideal for detecting such light because the emitted photons would be concentrated at the sphere's centre, whereas any background light bouncing off the mirror would pass through a focus midway between the sphere's surface and centre. A receiver placed at the centre could then pick up the dark-matter-generated photons, if tuned to their frequency – which is related to the mass of the incoming hidden photons – with mirror and receiver shielded as much as possible from stray electromagnetic waves.

Ideal mirror at hand

Fortunately for the team, an ideal mirror is at hand: a 13 m² aluminium mirror used in tests during the construction of the Pierre Auger Observatory and located at the Karlsruhe Institute of Technology. Döbrich and co-workers have got together with several researchers from Karlsruhe, and the collaboration is now readying the mirror by adjusting the position of each of its 36 segments to minimize the spot size of the focused waves. They are also measuring background radiation within the shielded room that will house the experiment. As for receivers, the most likely initial option is a set of low-noise photomultiplier tubes for measurements of visible light, which corresponds to hidden-photon masses of about 1 eV/c². Another obvious choice is a receiver for gigahertz radiation, which corresponds to masses less than 0.001 eV/c²; however, this latter set-up would require more shielding.

Dark matter composition research - WIMP

The WIMP (Weakly interactive massive particles) form a class of heavy particles, interacting slightly with matter, and constitute excellent candidates with the nonbaryonic dark matter. The neutralino postulated by the supersymmetric extensions of the standard model of particle physics. The idea of supersymmetry is to associate each boson to a fermion and vice versa. Each particle is then given a super-partner, having identical properties (mass, load), but with a spin which differs by 1/2. Thus, the number of particles is doubled. For example, the photon is accompanied by a photino, the graviton by a gravitino, the electron of a selectron, etc. Following the impossibility to detect a 511 keV boson (the electron partner), the physicists had to re-examine the idea of an exact symmetry. Symmetry is 'broken' and superpartners have a very important mass. One of these superparticles called LSP (Lightest Supersymmetric Particle) is the lightest of all. In most of the supersymmetric theories (without violation of the R-parity) the LSP is a stable particle because it cannot disintegrate in a lighter element. It is of neutral color and electric charge and is then only sensitive to weak interaction (weak nuclear force). It is then an excellent candidate for the not-baryonic dark matter. [11]

Weakly interacting massive particles

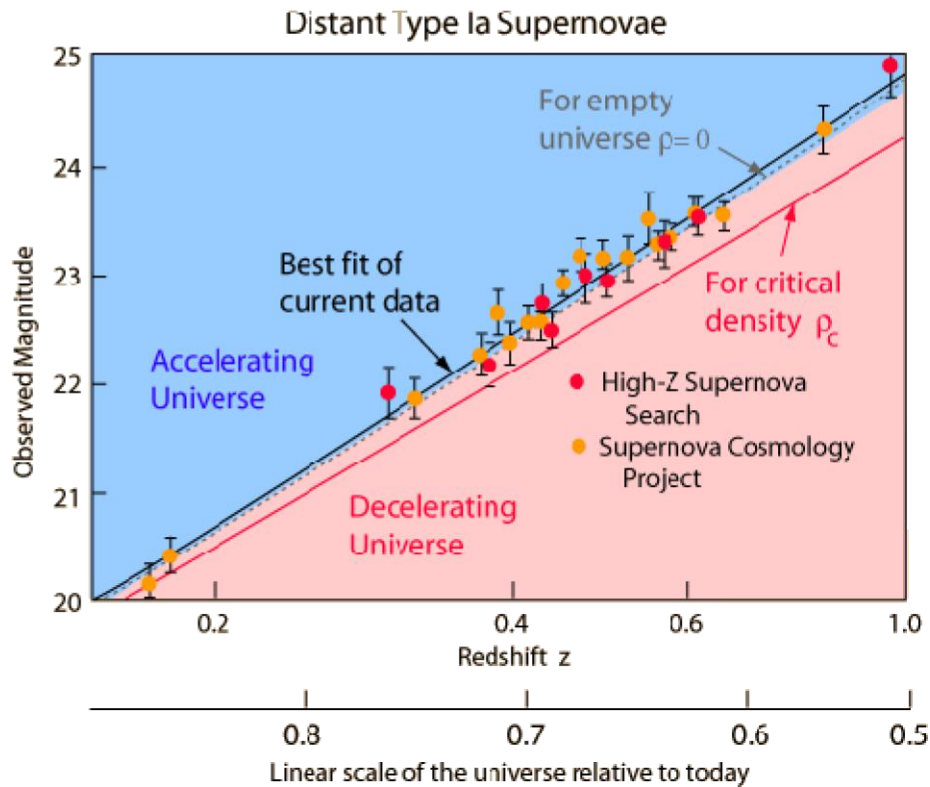
In particle physics and astrophysics, weakly interacting massive particles, or WIMPs, are among the leading hypothetical particle physics candidates for dark matter. The term "WIMP" is given to a dark matter particle that was produced by falling out of thermal equilibrium with the hot dense plasma of the early universe, although it is often used to refer to any dark matter candidate that interacts with standard particles via a force similar in strength to the weak nuclear force. Its name comes from the fact that obtaining the correct abundance of dark matter today via thermal production requires a self-annihilation cross section, which is roughly what is expected for a new particle in the 100 GeV mass range that interacts via the electroweak force. This apparent coincidence is known as the "WIMP miracle". Because supersymmetric extensions of the standard model of particle physics readily predict a new particle with these properties, a stable supersymmetric partner has long been a prime WIMP candidate. However, recent null results from direct detection experiments including LUX and SuperCDMS, along with the failure to produce evidence of supersymmetry in the Large Hadron Collider (LHC) experiment has cast doubt on the simplest WIMP hypothesis. Experimental efforts to detect WIMPs include the search for products of WIMP annihilation, including gamma

rays, neutrinos and cosmic rays in nearby galaxies and galaxy clusters; direct detection experiments designed to measure the collision of WIMPs with nuclei in the laboratory, as well as attempts to directly produce WIMPs in colliders such as the LHC. [10]

Evidence for an accelerating universe

One of the observational foundations for the big bang model of cosmology was the observed expansion of the universe. [9] Measurement of the expansion rate is a critical part of the study, and it has been found that the expansion rate is very nearly "flat". That is, the universe is very close to the critical density, above which it would slow down and collapse inward toward a future "big crunch". One of the great challenges of astronomy and astrophysics is distance measurement over the vast distances of the universe. Since the 1990s it has become apparent that type Ia supernovae offer a unique opportunity for the consistent measurement of distance out to perhaps 1000 Mpc. Measurement at these great distances provided the first data to suggest that the expansion rate of the universe is actually accelerating. That acceleration implies an energy density that acts in opposition to gravity which would cause the expansion to accelerate. This is an energy density which we have not directly detected observationally and it has been given the name "dark energy".

The type Ia supernova evidence for an accelerated universe has been discussed by Perlmutter and the diagram below follows his illustration in Physics Today.



The data summarized in the illustration above involve the measurement of the redshifts of the distant supernovae. The observed magnitudes are plotted against the redshift parameter z . Note that there are a number of Type Ia supernovae around $z=0.6$, which with a Hubble constant of 71 km/s/mbpc is a distance of about 5 billion light years.

Equation

The cosmological constant Λ appears in Einstein's field equation [5] in the form of

$$R_{\mu\nu} - \frac{1}{2}R g_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4}T_{\mu\nu},$$

where R and g describe the structure of spacetime, T pertains to matter and energy affecting that structure, and G and c are conversion factors that arise from using traditional units of measurement. When Λ is zero, this reduces to the original field equation of general relativity. When T is zero, the field equation describes empty space (the vacuum).

The cosmological constant has the same effect as an intrinsic energy density of the vacuum, ρ_{vac} (and an associated pressure). In this context it is commonly moved onto the right-hand side of the equation, and defined with a proportionality factor of 8π : $\Lambda = 8\pi\rho_{vac}$, where unit conventions of general relativity are used (otherwise factors of G and c would also appear). It is common to quote values of energy density directly, though still using the name "cosmological constant".

A positive vacuum energy density resulting from a cosmological constant implies a negative pressure, and vice versa. If the energy density is positive, the associated negative pressure will drive an accelerated expansion of the universe, as observed. (See dark energy and cosmic inflation for details.)

Explanatory models

Models attempting to explain accelerating expansion include some form of dark energy, dark fluid or phantom energy. The most important property of dark energy is that it has negative pressure which is distributed relatively homogeneously in space. The simplest explanation for dark energy is that it is a cosmological constant or vacuum energy; this leads to the Lambda-CDM model, which is generally known as the Standard Model of Cosmology as of 2003-2013, since it is the simplest model in good agreement with a variety of recent observations.

Dark Matter and Energy

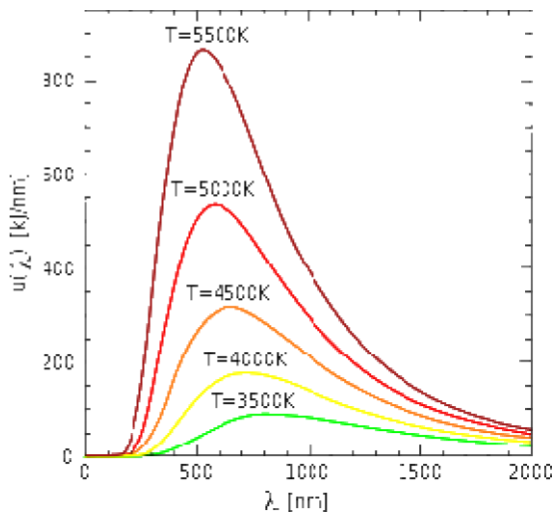
Dark matter is a type of matter hypothesized in astronomy and cosmology to account for a large part of the mass that appears to be missing from the universe. Dark matter cannot be seen directly with telescopes; evidently it neither emits nor absorbs light or other electromagnetic radiation at any significant level. It is otherwise hypothesized to simply be matter that is not reactant to light. Instead, the existence and properties of dark matter are inferred from its gravitational effects on visible matter, radiation, and the large-scale structure of the universe. According to the Planck mission team, and based on the standard model of cosmology, the total mass–energy of the known universe contains 4.9% ordinary matter, 26.8% dark matter and 68.3% dark energy. Thus, dark matter is estimated to constitute 84.5% of the total matter in the universe, while dark energy plus dark matter constitute 95.1% of the total content of the universe. [6]

Cosmic microwave background

The cosmic microwave background (CMB) is the thermal radiation assumed to be left over from the "Big Bang" of cosmology. When the universe cooled enough, protons and electrons combined to form neutral atoms. These atoms could no longer absorb the thermal radiation, and so the universe became transparent instead of being an opaque fog. [7]

Thermal radiation

Thermal radiation is electromagnetic radiation generated by the thermal motion of charged particles in matter. All matter with a temperature greater than absolute zero emits thermal radiation. When the temperature of the body is greater than absolute zero, interatomic collisions cause the kinetic energy of the atoms or molecules to change. This results in charge-acceleration and/or dipole oscillation which produces electromagnetic radiation, and the wide spectrum of radiation reflects the wide spectrum of energies and accelerations that occur even at a single temperature. [8]



Electromagnetic Field and Quantum Theory

Needless to say that the accelerating electrons of the steady stationary current are a simple demystification of the magnetic field, by creating a decreasing charge distribution along the wire, maintaining the decreasing U potential and creating the \underline{A} vector potential experienced by the electrons moving by \underline{v} velocity relative to the wire. This way it is easier to understand also the time dependent changes of the electric current and the electromagnetic waves as the resulting fields moving by c velocity.

It could be possible something very important law of the nature behind the self maintaining \underline{E} accelerating force by the accelerated electrons. The accelerated electrons created electromagnetic fields are so natural that they occur as electromagnetic waves traveling with velocity c. It shows that the electric charges are the result of the electromagnetic waves diffraction.

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

The bridge between the classical and quantum theory is based on this intrinsic acceleration of the spin, explaining also the Heisenberg Uncertainty Principle. The particle – wave duality of the electric charges and the photon makes certain that they are both sides of the same thing. Basing the gravitational force on the accelerating Universe caused magnetic force and the Planck Distribution

Law of the electromagnetic waves caused diffraction gives us the basis to build a Unified Theory of the physical interactions. [4]

Lorentz transformation of the Special Relativity

In the referential frame of the accelerating electrons the charge density lowering linearly because of the linearly growing way they takes every next time period. From the referential frame of the wire there is a parabolic charge density lowering.

The difference between these two referential frames, namely the referential frame of the wire and the referential frame of the moving electrons gives the relativistic effect. Important to say that the moving electrons presenting the time coordinate, since the electrons are taking linearly increasing way every next time period, and the wire presenting the geometric coordinate. The Lorentz transformations are based on moving light sources of the Michelson - Morley experiment giving a practical method to transform time and geometric coordinates without explaining the source of this mystery.

The real mystery is that the accelerating charges are maintaining the accelerating force with their charge distribution locally. The resolution of this mystery that the charges are simply the results of the diffraction patterns, that is the charges and the electric field are two sides of the same thing. Otherwise the charges could exceed the velocity of the electromagnetic field.

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 Classical Relativistic effect

The moving charges are self maintain the electromagnetic field locally, causing their movement and this is the result of their acceleration under the force of this field.

In the classical physics the charges will distributed along the electric current so that the electric potential lowering along the current, by linearly increasing the way they take every next time period because this accelerated motion.

Electromagnetic inertia and Gravitational attraction

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.

It looks clear that the growing acceleration results the relativistic growing mass - limited also with the velocity of the electromagnetic wave.

Since $E = h\nu$ and $E = mc^2$, $m = h\nu/c^2$ that is the m depends only on the ν frequency. It means that the mass of the proton and electron are electromagnetic and the result of the electromagnetic induction, caused by the changing acceleration of the spinning and moving charge! It could be that the m_0 inertial mass is the result of the spin, since this is the only accelerating motion of the electric charge. Since the accelerating motion has different frequency for the electron in the atom and the proton, they masses are different, also as the wavelengths on both sides of the diffraction pattern, giving equal intensity of radiation.

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.

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.

Electromagnetic inertia and mass

Electromagnetic Induction

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Relativistic change of mass

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The frequency dependence of mass

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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. [1]

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

Gravity from the point of view of quantum physics

The Gravitational force

The gravitational attractive force is basically a magnetic force.

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

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

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

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

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

The 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. [2]

Conclusions

Researchers predict that axions, if they exist, would be produced invisibly by the Sun, but would convert to X-rays as they hit Earth's magnetic field. This X-ray signal should in theory be strongest when looking through the sunward side of the magnetic field, as this is where the Earth's magnetic

field is strongest. The high frequency of the X-ray and the uncompensated Planck distribution makes the axion a good candidate to be dark matter.

Hidden photons are predicted in some extensions of the Standard Model of particle physics, and unlike WIMPs they would interact electromagnetically with normal matter.

In particle physics and astrophysics, weakly interacting massive particles, or WIMPs, are among the leading hypothetical particle physics candidates for dark matter.

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 electric currents causing self maintaining electric potential is the source of the special and general relativistic effects. The Higgs Field is the result of the electromagnetic induction. The Graviton is two photons together. [3]

References

[1] 3 Dimensional String Theory

Author: George Rajna

Publisher: Academia.edu

http://www.academia.edu/3834454/3_Dimensional_String_Theory

[2] Graviton Production By Two Photon and Electron-Photon Processes In Kaluza-Klein Theories With Large Extra Dimensions <http://arxiv.org/abs/hep-ph/9909392>

[3] Higgs Field and Quantum Gravity

Author: George Rajna

Publisher: Academia.edu

http://www.academia.edu/4158863/Higgs_Field_and_Quantum_Gravity

[4] The Magnetic field of the Electric current

Author: George Rajna

Publisher: Academia.edu

https://www.academia.edu/3833335/The_Magnetic_field_of_the_Electric_current

[5] http://en.wikipedia.org/wiki/Einstein_field_equations

- [6] http://en.wikipedia.org/wiki/Dark_matter
- [7] http://en.wikipedia.org/wiki/Cosmic_microwave_background
- [8] http://en.wikipedia.org/wiki/Thermal_radiation
- [9] <http://hyperphysics.phy-astr.gsu.edu/hbase/astro/univacc.html>
- [10] http://en.wikipedia.org/wiki/Weakly_interacting_massive_particles
- [11] <http://www.darkmatterphysics.com/WIMP.htm>
- [12] <http://physicsworld.com/cws/article/news/2014/oct/13/dark-matter-could-light-up-giantmirror>
- [13] <http://sciencealert.com.au/news/20141810-26360-2.html>
- [14] <http://en.wikipedia.org/wiki/Axion>
- [15] Exchanges of identity in deep space
<https://phys.org/news/2017-09-exchanges-identity-deep-space.html>
- [16] Synopsis: Dark Photon Conjecture Fizzles
<https://physics.aps.org/synopsis-for/10.1103/PhysRevLett.119.131804>
- [17] Gravitational wave detectors could shed light on dark matter <https://phys.org/news/2017-10-gravitational-detectors-dark.html>
- [18] Gravitational wave detectors to search for dark matter
<https://phys.org/news/2018-08-gravitational-detectors-dark.html>
- [19] Large-scale simulations could shed light on the 'dark' elements that make up most of our cosmos
<https://phys.org/news/2018-08-large-scale-simulations-dark-elements-cosmos.html>
- [20] Dark matter clusters could reveal nature of dark energy
<https://phys.org/news/2018-09-dark-clusters-reveal-nature-energy.html>
- [21] This is how a 'fuzzy' universe may have looked
<https://phys.org/news/2019-10-fuzzy-dark-disrupts-conventional.html>

