

Unexpected Rain on Sun

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The sun's magnetic field is ten times stronger than previously believed, new research from Queen's University Belfast and Aberystwyth University has revealed. [19]

University of Southern Denmark researchers have conducted simulations of dark matter particles hitting the Earth. [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.

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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.

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Unexpected rain on sun links two solar mysteries

For five months in mid 2017, Emily Mason did the same thing every day. Arriving to her office at NASA's Goddard Space Flight Center in Greenbelt, Maryland, she sat at her desk, opened up her computer, and stared at images of the Sun—all day, every day. "I probably looked through three or five years' worth of data," Mason estimated. Then, in October 2017, she stopped. She realized she had been looking at the wrong thing all along.

Mason, a graduate student at The Catholic University of America in Washington, D.C., was searching for coronal rain: giant globs of plasma, or electrified gas, that drip from the Sun's outer atmosphere back to its surface. But she expected to find it in helmet streamers, the million-mile tall magnetic loops—named for their resemblance to a knight's pointy helmet—that can be seen protruding from the Sun during a [solar eclipse](#). Computer simulations predicted the coronal rain could be found there. Observations of the solar wind, the gas escaping from the Sun and out into space, hinted that the rain might be happening. And if she could just find it, the underlying rain-making physics would have major implications for the 70-year-old mystery of why the Sun's outer atmosphere, known as the corona, is so much hotter than its surface. But after nearly half a year of searching, Mason just couldn't find it. "It was a lot of looking," Mason said, "for something that never ultimately happened."

The problem, it turned out, wasn't what she was looking for, but where. In a paper published today in the *Astrophysical Journal Letters*, Mason and her coauthors describe the first observations of coronal rain in a smaller, previously overlooked kind of magnetic loop on the Sun. After a long, winding search in the wrong direction, the findings forge a new link between the anomalous heating of the corona and the source of the slow solar wind—two of the biggest mysteries facing solar science today.

How It Rains on the Sun

Observed through the high-resolution telescopes mounted on NASA's SDO spacecraft, the Sun—a hot ball of plasma, teeming with [magnetic field lines](#) traced by giant, fiery loops—seems to have few physical similarities with Earth. But our home planet provides a few useful guides in parsing the Sun's chaotic tumult: among them, rain.

On Earth, rain is just one part of the larger water cycle, an endless tug-of-war between the push of heat and pull of gravity. It begins when liquid water, pooled on the planet's surface in oceans, lakes, or streams, is heated by the Sun. Some of it evaporates and rises into the atmosphere, where it cools and condenses into clouds. Eventually, those clouds become heavy enough that gravity's pull becomes irresistible and the water falls back to Earth as rain, before the process starts anew.

On the Sun, Mason said, coronal rain works similarly, "but instead of 60-degree water you're dealing with a million-degree plasma." Plasma, an electrically-charged gas, doesn't pool like water, but instead traces the magnetic loops that emerge from the Sun's surface like a rollercoaster on tracks. At the loop's foot points, where it attaches to the Sun's surface, the plasma is superheated from a few thousand to over 1.8 million degrees Fahrenheit. It then expands up the loop and gathers at its peak, far from the heat source. As the plasma cools, it condenses and gravity lures it down the loop's legs as coronal rain.

Mason was looking for coronal rain in helmet streamers, but her motivation for looking there had more to do with this underlying heating and cooling cycle than the rain itself. Since at least the mid-1990s, scientists have known that helmet streamers are one source of the slow solar wind, a comparatively slow, dense stream of gas that escapes the Sun separately from its fast-moving counterpart. But measurements of the slow solar wind gas revealed that it had once been heated to an extreme degree before cooling and escaping the Sun. The cyclical process of heating and

cooling behind coronal rain, if it was happening inside the helmet streamers, would be one piece of the puzzle.



Coronal rain, like that shown in this movie from NASA's SDO in 2012, is sometimes observed after solar eruptions, when the intense heating associated with a solar flare abruptly cuts off after the eruption and the remaining plasma cools and falls back to the solar surface. Mason was searching for coronal rain not associated with eruptions, but instead caused by a cyclical process of heating and cooling similar to the water cycle on Earth. Credit: Credits: NASA's Solar Dynamics Observatory/Scientific Visualization Studio/Tom Bridgman, Lead Animator

The other reason connects to the coronal heating problem—the mystery of how and why the Sun's outer atmosphere is some 300 times hotter than its surface. Strikingly, simulations have shown that coronal rain only forms when heat is applied to the very bottom of the loop. "If a loop has coronal rain on it, that means that the bottom 10% of it, or less, is where coronal heating is happening," said Mason. Raining loops provide a measuring rod, a cutoff point to determine where the corona gets heated. Starting their search in the largest loops they could find—giant helmet streamers—seemed like a modest goal, and one that would maximize their chances of success.

She had the best data for the job: Images taken by NASA's Solar Dynamics Observatory, or SDO, a spacecraft that has photographed the Sun every twelve seconds since its launch in 2010. But nearly half a year into the search, Mason still hadn't observed a single drop of rain in a helmet streamer. She had, however, noticed a slew of tiny magnetic structures, ones she wasn't familiar with. "They were really bright and they kept drawing my eye," said Mason. "When I finally took a look at them, sure enough they had tens of hours of rain at a time."

At first, Mason was so focused on her helmet streamer quest that she made nothing of the observations. "She came to group meeting and said, 'I never found it—I see it all the time in these other structures, but they're not helmet streamers,'" said Nicholeen Viall, a solar scientist at

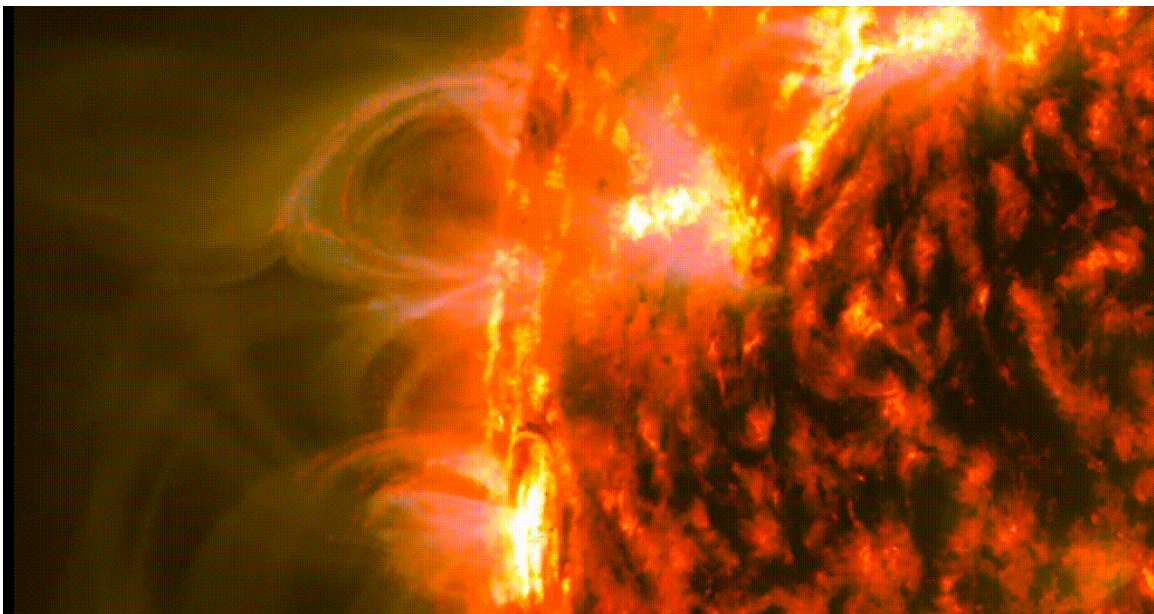
Goddard, and a coauthor of the paper. "And I said, 'Wait...hold on. Where do you see it? I don't think anybody's ever seen that before!'"

A Measuring Rod for Heating

These structures differed from helmet streamers in several ways. But the most striking thing about them was their size.

"These loops were much smaller than what we were looking for," said Spiro Antiochos, who is also a solar physicist at Goddard and a coauthor of the paper. "So that tells you that the heating of the corona is much more localized than we were thinking."

While the findings don't say exactly how the corona is heated, "they do push down the floor of where coronal heating could happen," said Mason. She had found raining loops that were some 30,000 miles high, a mere two percent the height of some of the helmet streamers she was originally looking for. And the rain condenses the region where the key coronal heating can be happening. "We still don't know exactly what's heating the corona, but we know it has to happen in this layer," said Mason.



Mason's article analyzed three observations of Raining Null-Point Topologies, or RNTPs, a previously overlooked magnetic structure shown here in two wavelengths of extreme ultraviolet light. The coronal rain observed in these comparatively small magnetic loops suggests that the corona may be heated within a far more restricted region than previously expected. Credit: NASA's Solar Dynamics Observatory/Emily Mason

A New Source for the Slow Solar Wind

But one part of the observations didn't jibe with previous theories. According to the current understanding, coronal rain only forms on closed loops, where the plasma can gather and cool without any means of escape. But as Mason sifted through the data, she found cases where rain was forming on open magnetic field lines. Anchored to the Sun at only one end, the other end of

these open field lines fed out into space, and plasma there could escape into the solar wind. To explain the anomaly, Mason and the team developed an alternative explanation—one that connected rain on these tiny magnetic structures to the origins of the slow solar wind.

In the new explanation, the raining plasma begins its journey on a closed loop, but switches—through a process known as magnetic reconnection—to an open one. The phenomenon happens frequently on the Sun, when a closed loop bumps into an open field line and the system rewires itself. Suddenly, the superheated plasma on the closed loop finds itself on an open field line, like a train that has switched tracks. Some of that plasma will rapidly expand, cool down, and fall back to the Sun as coronal rain. But other parts of it will escape—forming, they suspect, one part of the slow solar wind.

Mason is currently working on a computer simulation of the new explanation, but she also hopes that soon-to-come observational evidence may confirm it. Now that Parker Solar Probe, launched in 2018, is traveling closer to the Sun than any spacecraft before it, it can fly through bursts of slow solar wind that can be traced back to the Sun—potentially, to one of Mason's coronal rain events. After observing coronal rain on an open field line, the outgoing plasma, escaping to the solar wind, would normally be lost to posterity. But no longer. "Potentially we can make that connection with Parker Solar Probe and say, that was it," said Viall.

Digging Through the Data

As for finding coronal rain in helmet streamers? The search continues. The simulations are clear: the rain should be there. "Maybe it's so small you can't see it?" said Antiochos. "We really don't know."

But then again, if Mason had found what she was looking for she might not have made the discovery—or have spent all that time learning the ins and outs of solar data.

"It sounds like a slog, but honestly it's my favorite thing," said Mason. "I mean that's why we built something that takes that many images of the Sun: So we can look at them and figure it out." [20]

Researchers find that the sun's magnetic field is ten times stronger than previously believed

The sun's magnetic field is ten times stronger than previously believed, new research from Queen's University Belfast and Aberystwyth University has revealed.

The new finding was discovered by Dr. David Kuridze, Research Fellow at Aberystwyth University. Dr. Kuridze began the research when he was based at Queen's University Belfast and completed it when he moved to Aberystwyth University in 2017. He is a leading authority on the use of ground-based telescopes to study the sun's corona, the ring of bright light visible during a total eclipse.

Working from the Swedish 1-m Solar Telescope at Roque de los Muchachos Observatory, La Palma in the Canary Islands, Dr. Kuridze studied a particularly strong solar flare which erupted near the surface of the sun on 10 September 2017.

A combination of favourable conditions and an element of luck enabled the team to determine the strength of the flare's [magnetic field](#) with unprecedented accuracy. The researchers believe the findings have the potential to change our understanding of the processes that happen in the sun's immediate atmosphere.

Speaking about the find, Dr. Kuridze said: "Everything that happens in the sun's outer atmosphere is dominated by the magnetic [field](#), but we have very few measurements of its strength and spatial characteristics.

"These are critical parameters, the most important for the physics of the solar corona. It is a little like trying to understand the Earth's climate without being able to measure its temperature at various geographical locations.

"This is the first time we have been able to measure accurately the magnetic field of the coronal loops, the building blocks of the sun's magnetic corona, with such a level of accuracy."

Measuring 1,400,000 kilometres across (109 times larger than Earth) and 150,000,000 kilometres from Earth, the sun's corona extends millions of kilometres above the surface.

Solar flares appear as bright flashes and occur when magnetic energy that has built up in the solar atmosphere is suddenly released.

Until now, successful measurement of the magnetic field has been hindered by the weakness of the signal from the sun's atmosphere that reaches Earth and carries information about the magnetic field, and limitations in the instrumentation available.

The magnetic fields reported in this study are similar to those of a typical fridge magnet and around 100 times weaker than the magnetic field encountered in an MRI scanner.

However, they are still responsible for the confinement of the solar plasma, which make up [solar flares](#), as far as 20,000 km above the sun's surface.

Over a 10-day period in September 2017, Dr. Kuridze studied an active area on the sun's surface which the team knew to be particularly volatile.

However, the telescope used can only focus on 1% of the sun's surface at any given time. As luck would have it, Dr. Kuridze was focused on exactly the right area and at the right time when the solar flare erupted.

These solar flares can lead to storms which, if they hit Earth, form the northern lights – the Aurora Borealis.

They can also disrupt [communications satellites](#) and GPS systems, as proved to be the case on this occasion in September 2017.

Professor Michail Mathioudakis from the School of Mathematics and Physics, Queen's University Belfast, who also worked on the project, added: "This is a unique set of observations that, for the first time, provide a detailed map of the magnetic field in coronal loops.

"This highly rewarding result was achieved due to the dedication and perseverance of our early career scientists who planned and executed the observations. The methodology used in this work and the result itself, will open new avenues in the study of the solar corona." [19]

How does it look when Earth is bombarded with dark matter?

University of Southern Denmark researchers have conducted simulations of dark matter particles hitting the Earth. Physicists believe that Earth collides with uncountable dark matter particles as it hurtles through space. Although no one has ever seen these mysterious particles, there is no question among physicists about their existence. Researchers have installed detectors around the globe in the hope of detecting them.

Dark matter particles can penetrate all other forms of matter, which means that they may even be able to traverse through Earth without losing any energy whatsoever. On the other hand, their impact with ordinary matter may hamper them slightly, resulting in a loss of energy.

"We just don't know, and that definitely doesn't make it any easier looking for them," said Timon Emken, a Ph.D. student at the Centre for Cosmology and Particle Physics Phenomenology (CP3) at the University of Southern Denmark. In order to learn more about how dark matter particles react with normal matter, Emken enlisted the aid of a supercomputer. The result was a program that can simulate the collision of dark matter particles with the Earth.

"Now, I can ask the computer to show me on the screen what happens when a [dark matter particle](#) hits Earth. For example, I can see on the screen which trajectory the particle would take from when it hits the surface of our planet until it leaves again," he explained.

The simulation is called DaMaSCUS, and it gives physicists the world over a new opportunity to test out various theories. The program is freely available, and the work that went into it has been published in the journal *JCAP*.

In the standard paradigm, dark matter particles transverse the Earth with a very low probability of interacting with atoms comprising the planet. However, underground detectors are tuned to do just that, i.e., to capture rare events of dark matter particle collisions with an atom inside a [detector](#).

"But what if dark matter particles do not follow the standard paradigm? What if they actually interact strongly enough with ordinary atoms, that, as they cross the surface of the Earth and travel underground, they lose enough energy to become undetectable? In that case, we will never spot them using standard techniques," said Associate Professor Chris Kouvaris from CP3.

One of the things he is currently investigating is the possibility that dark matter particles scatter significantly as they transverse the Earth. Kouvaris and Emken used DaMaSCUS to demonstrate how such a scenario would play out. DaMaSCUS simulates billions of dark matter particles penetrating the Earth and scattering significantly with underground atoms, zig-zagging after every single collision.

"If this is the case, underground scatterings of dark matter particles with atoms might make the dark matter particles lose enough energy to be detectable in the underground detectors that we deploy today."

Kouvaris' proposal is therefore to take a different approach to looking for the elusive particles. Today, there are a number of detectors situated around two kilometres below the Earth's surface. If dark matter interacts weakly with [ordinary matter](#) as neutrinos do, only these two particles can penetrate kilometres of the Earth's crust without being stopped. Thus, deep site detectors evade contamination of the signal from unwanted cosmic and terrestrial radiation and background noise.

However, according to Chris Kouvaris, if dark matter is light, it could actually interact strongly with ordinary atoms, losing energy on the way to the detector, and this can make deep site detectors unable to catch it.

"In that case, it would make more sense to search for dark matter signals using detectors on the Earth's surface," he said.

To overcome the problem of background noise, he suggests that instead of trying to distinguish dark matter from background noise, researchers should look for a daily varying signal in surface or low depth detectors.

Because the Earth is moving with respect to the center of the galaxy, dark matter hits the Earth predominantly from one direction. However, due to the rotation of the Earth around its own axis, dark matter [particles](#) that come from the direction of the dark matter wind travel different distances during the 24-hour period of a day.

The larger the distance travelled underground, the higher the probability of underground scattering. This is what creates the daily variation of the signal. The optimal location to exploit this effect is in the southern hemisphere at approximately 40 degrees latitude, i.e. in countries such as Argentina, Chile and New Zealand.

Using DaMaSCUS, Kouvaris and Emken can determine precisely the amplitude and phase of this daily varying signal, which could lead to the discovery of dark matter, if this scenario turns out to be true. Kouvaris is now collaborating with the [dark matter experiment](#) DAMIC, which has a portable detector that could potentially be used to test Kouvaris' theories. In the new phase of DAMIC, the portable detector will weigh 1 kg. It is made of silicon manufactured by the Danish company, TOPSIL.

It is thought that 27 percent of the universe consists of dark [matter](#). Scientists believe it binds galaxies together. However, no one really knows yet what [dark matter](#) is. [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 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.

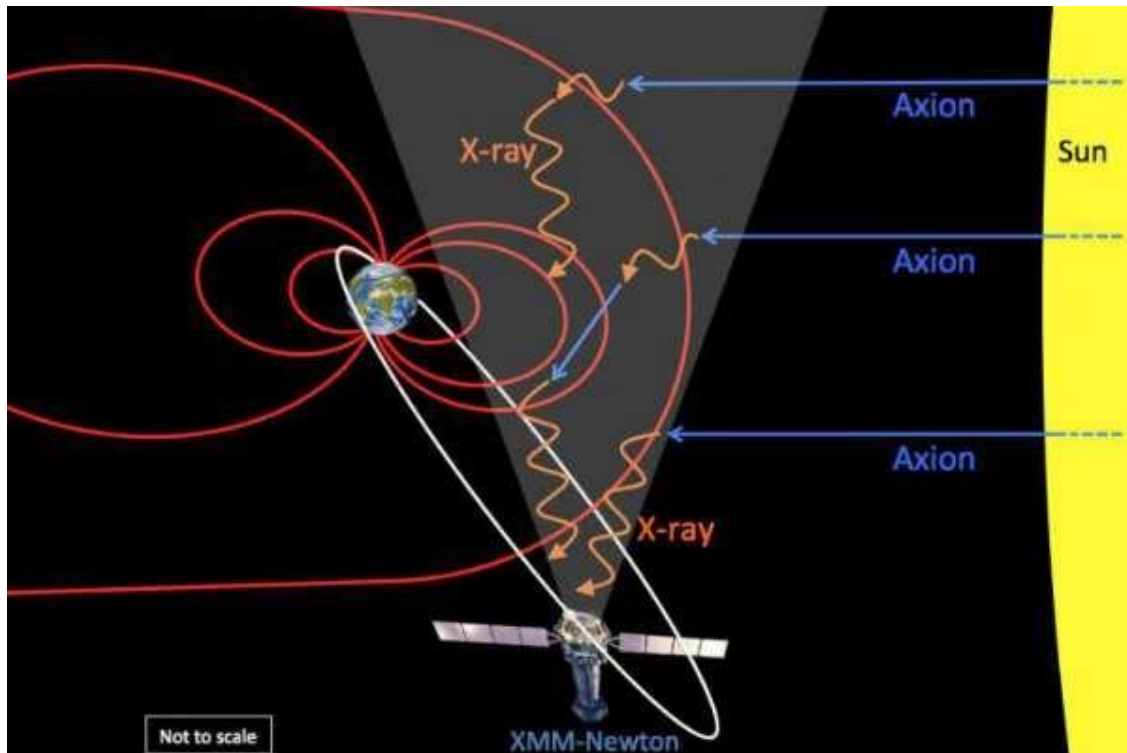
While we can't get too excited just yet - it will take years to confirm whether this signal really is dark matter - the discovery would completely change our understanding of how the Universe works. After all, dark matter is the force that holds our galaxies together, so learning more about it is pretty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

The researchers first detected the signal while searching through 15 years of measurements taken 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, detected 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 by 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

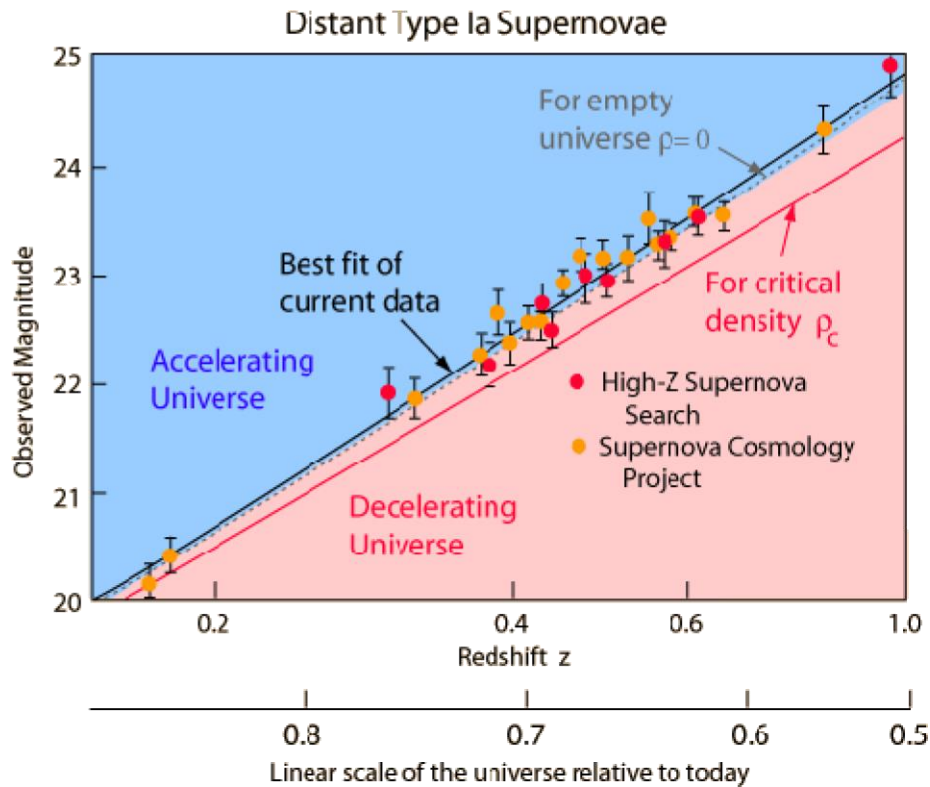
model of particle physics readily predict a new particle with these properties, a stable supersymmetric partner has long been a prime WIMP candidate. However, recent null results from direct detection experiments including LUX and SuperCDMS, along with the failure to produce evidence of supersymmetry 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

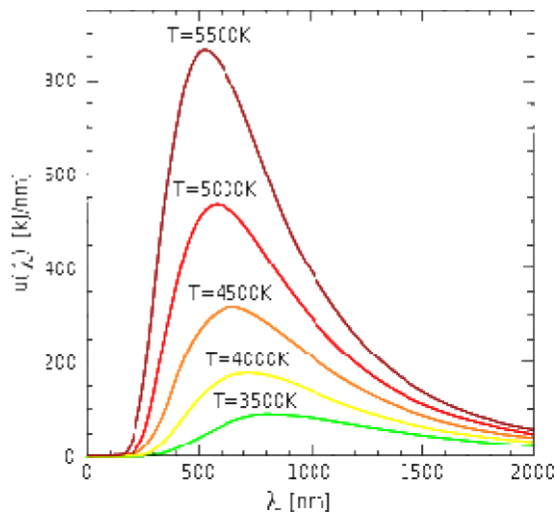
Dark matter is a type of matter hypothesized in astronomy and cosmology to account for a large part of the mass that appears to be missing from the universe. Dark matter cannot be seen directly with telescopes; evidently it neither emits nor absorbs light or other electromagnetic radiation at any significant 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 $E = hv$ and $E = mc^2$, $m = hv/c^2$ that is the m depends only on the v 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

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

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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]

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