Scalar Field Dark Matter

Astronomers have used data from NASA's Chandra X-ray Observatory to study the properties of dark matter, the mysterious, invisible substance that makes up a majority of matter in the universe. The study, which involves 13 galaxy clusters, explores the possibility that dark matter may be more "fuzzy" than "cold," perhaps even adding to the complexity surrounding this cosmic conundrum. [18]

The idea is called "FDM", for "fuzzy dark matter". It posits that an extremely light boson, one almost exactly massless in fact, could be responsible for the scale of galaxy halos we observe in the universe. [17]

Unlike x-rays that the naked eye can't see but equipment can measure, scientists have yet to detect dark matter after three decades of searching, even with the world's most sensitive instruments. [16]

Scientists have lost their latest round of hide-and-seek with dark matter, but they're not out of the game. [15]

A new study is providing evidence for the presence of dark matter in the innermost part of the Milky Way, including in our own cosmic neighborhood and the Earth's location. The study demonstrates that large amounts of dark matter exist around us, and also between us and the Galactic center. The result constitutes a fundamental step forward in the quest for the nature of dark matter. [14]

Researchers may have uncovered a way to observe dark matter thanks to a discovery involving X-ray emissions. [13]

Between 2009 and 2013, the Planck satellite observed relic radiation, sometimes called cosmic microwave background (CMB) radiation. Today, with a full analysis of the data, the quality of the map is now such that the imprints left by dark matter and relic neutrinos are clearly visible. [12]

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 Weak Interaction changes the temperature dependent Planck Distribution of the electromagnetic oscillations and changing the non-compensated dark matter rate, giving the responsibility to the sterile neutrino.

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Is dark matter 'fuzzy'?

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For several decades, astronomers have known about dark matter. Although it cannot be observed directly, dark matter does interact via gravity with normal, radiating matter (that is, anything made up of protons, neutrons, and electrons bundled into atoms). Capitalizing on this interaction, astronomers have studied the effects of dark matter using a variety of techniques, including observations of the motion of stars in galaxies, the motion of galaxies in galaxy clusters, and the distribution of X-ray emitting hot gas in galaxy clusters. Dark matter has also left an imprint on the radiation left over from the Big Bang 13.8 billion years ago.

However, astronomers have been struggling for decades to understand the detailed properties of dark matter. In other words, they would like to know how dark matter behaves in all environments, and, ultimately, what it is made of.

The most popular model assumes that dark matter is a particle more massive than a proton that is "cold", meaning that it moves at speeds much smaller than the speed of light. This model has been successful at explaining the structure of the universe on very large scales, much bigger than galaxies, but it has problems with explaining how matter is distributed on the smaller scales of galaxies.

For example, the cold dark matter model predicts that the density of dark matter in the center of galaxies is much higher than in surrounding regions close to the center. Because normal matter is attracted to the dark matter, it also should have a strong peak in density at the center of galaxies. However, astronomers observe that the density of both dark and normal matter in the center of galaxies is much more evenly spread out. Another issue with the cold dark matter model is that it predicts a much higher number of small galaxies orbiting around galaxies like the Milky Way than astronomers actually see.

To address these problems with the cold dark matter model, astronomers have come up alternative models where dark matter has very different properties. One such model takes advantage of the principle in quantum mechanics that each subatomic particle has a wave associated with it. If the dark matter particle has an extremely small mass, about ten thousand trillion trillion times smaller than an electron's mass, its corresponding wavelength will be about 3,000 light years. This distance from one peak of the wave to another is about one eighth of the distance between the Earth and the center of the Milky Way. By contrast, the longest wavelength of light, a radio wave, is only a few miles long.

Waves from different particles on these large scales can overlap and interfere with each other like waves on a pond, acting like a quantum system on galactic rather than atomic scales.

The large wavelength of the particles' wave means that the density of dark matter in the center of galaxies cannot be strongly peaked. Therefore to an observer outside a galaxy these particles would appear fuzzy if they could be directly detected, so this model has been called "fuzzy dark matter". Because the normal matter is attracted to the dark matter it will also be spread out over large scales. This would naturally explain the lack of a strong peak in the density of matter in the center of galaxies.

This simple model has been successful at explaining the amount and location of dark matter in small galaxies. For larger galaxies, a more complicated model of fuzzy dark matter has been needed. In this model, massive concentrations of dark matter can lead to multiple quantum states (called "excited states"), in which the dark matter particles can have different amounts of energy, similar to an atom with electrons in higher energy orbits. These excited states change how the density of dark matter varies with distance away from the center of the galaxy cluster.

In a new study, a team of scientists used Chandra observations of the hot gas in 13 galaxy clusters to see if the fuzzy dark matter model works at larger scales than that of galaxies. They used the Chandra data to estimate both the amount of dark matter in each cluster and how the density of this matter varies with distance away from the center of the galaxy cluster.

The graphic shows four of the 13 galaxies clusters used in the study. The clusters are, starting at the top left and going clockwise, Abell 262, Abell 383, Abell 1413, and Abell 2390. In each of these images, X-ray data from Chandra are pink, while optical data are red, green, and blue.

As with the studies of galaxies, the simplest model of fuzzy dark matter—where all particles have the lowest possible energy—did not agree with the data. However, they found that the model where the particles had different amounts of energy—the "excited states—did give good agreement with the data. In fact, the fuzzy dark matter model may match the observations of these 13 galaxy clusters just as well or even better than a model based on cold dark matter.

This result shows that the fuzzy dark matter model may be a viable alternative to cold dark matter, but further work is needed to test this possibility. An important effect of the excited states is to give ripples, or oscillations, in the density of dark matter as a function of distance away from the center of the cluster. This would produce ripples in the density of normal matter. The expected magnitude of these ripples is less than the current uncertainties in the data. A more detailed study is needed to test this prediction of the model.

A paper describing these results was recently accepted for publication in the Monthly Notices of the Royal Astronomical Society and is available online. The authors are Tula Bernal (National Polytechnic Institute, Mexico City), Victor Robles (University of California, Irvine), and Tonatiuh Matos (National Polytechnic Institute). [18]

Is Dark Matter A Very Light Boson? Witten Says It Might

The mystery of what clumps galaxy clusters together, and provides for a quarter of the matter-energy budget of the universe, really looks like the most important scientific question we face today. There is nowadays compelling evidence of the correctness of the standard cosmological model, coming from the cosmic microwave background maps provided lastly by Planck as well as from a number of other observations - of supernovae, galaxy clusters, galaxy rotation curves, etcetera. So we know there has to be dark matter out there. But what is it?

10 years ago many of my colleagues, experimental physicists from ATLAS and CMS, looked totally sold out to the idea that they would find the answer by smashing protons against protons at the LHC. Indeed, for a while it looked like the "cosmic coincidence" was too strong an argument to be false. A stable, massive neutral particle produced copiously by the Big Bang would still be around today, and its abundance would match the missing matter budget of the universe if its mass were in the few 100-GeV ballpark; such a particle would automatically have the right couplings (to be produced in the required abundance) for a neutralino, the lightest SUSY particle.

But SUSY has not shown up at the LHC. With the 2016 collisions acquired by ATLAS and CMS we will put even stronger bounds on Supersymmetry, but already what we did this far makes SUSY a less-than-likely hypothesis - most of the simplest theory instantiations have been wiped off the board by direct searches, and what remains are uglier versions of the theory, less attractive and "fine-tuned". Beware - SUSY might still be _the_ correct theory, and we might still find it. But that would be more of a surprise now than it looked 10 years ago.

So what is dark matter? Is it primordial black holes? The LIGO-VIRGO discovery of 30-solar-mass mergers has revived this question because such intermediate-mass black holes were thought to be less abundant in the universe. I am not an expert so I am unable to assess critically this question, but experts say it is a unlikely explanation, for a few good reasons.

A paper that appeared on the arxiv a few days ago offers a very different solution to the question. The article, titled "On the hypothesis that cosmological dark matter is composed of ultra-light bosons", is authored by Hui, Ostriker, Tremaine and Witten, and it deserves a lot of attention -of course, anything Witten writes does; but this paper is also quite readable, as opposed to many string theory works which remain inscrutable to most of us. The authors take in consideration a hypothesis that is not new, and study it in detail, coming to several interesting conclusions.

The idea is called "FDM", for "fuzzy dark matter". It posits that an extremely light boson, one almost exactly massless in fact, could be responsible for the scale of galaxy halos we observe in the universe. A particle with a mass in the 10^-22 eV range would have a de Broglie wavelength of a kiloparsec or so. Its abundant presence in the universe would form halos only larger than a certain scale, at variance with what could be predicted in the cold-dark-matter model.

The authors consider the particle physics motivations for such a light boson, and point out many consequences of its existence, crucially indicating how the model could be falsified or proven by experimental investigations. In particular, the FDM would create a stationary core in the halo, a sort of soliton, which would have a distinct signature in the rotational curves of galaxies.

Another point made already in the abstract of the paper is that the Fornax dwarf galaxy (see picture, right) seems to have globular clusters that could not be there if the dark matter in that galaxy was of the "ordinary" kind predicted by the CDM paradigm; the FDM solution would thus "explain" the existence of this peculiar system better. [17]

The search for dark matter

At least a quarter of the universe is invisible.

Unlike x-rays that the naked eye can't see but equipment can measure, scientists have yet to detect dark matter after three decades of searching, even with the world's most sensitive instruments. But dark matter is so fundamental to physics that scientists supported by the Department of Energy's Office of Science are searching for it in some of the world's most isolated locales, from deep underground to outer space.

"Without dark matter, it's possible that we would not exist," said Michael Salamon, a DOE Office of Science High Energy Physics (HEP) program manager.

The Office of Science supports a comprehensive program in the hunt for dark matter and other phenomena that help scientists better understand how the universe functions at its most fundamental level.

Traces of Dark Matter's Influence

What we do know about dark matter comes from the ways it's influenced the universe nearly as far back as the Big Bang. Like paw prints left by an elusive animal, the cosmos is full of signs of dark matter's existence, but we haven't actually seen the creature itself.

Astronomer Fritz Zwicky discovered dark matter in 1933 when he was examining the Coma Cluster of galaxies. He noticed they were emitting much less light than they should have been, considering their mass. After running some calculations, he realized that the majority of the cluster's mass wasn't emitting light or electromagnetic radiation at all.

But it wasn't just that cluster. Today, we know that visible matter accounts for only five percent of the universe's total mass-energy. (As Einstein's famous equation, E=mc2, tells us, the concepts of matter and energy are intrinsically linked.) Dark matter makes up about a quarter of the total mass-energy, while dark energy comprises the rest.

Since Zwicky's initial discovery, scientists have found a number of other tell-tale signs. Examining the rotation of galaxies in the 1970s, astronomer Vera Rubin realized that they don't move the way they "should" if only visible matter exists. Her discovery of the galaxy rotation problem provides some of the strongest evidence for dark matter's existence. Similarly, cosmic background radiation, which has a record of the early universe imprinted on it, reflects dark matter's presence.

Scientists think dark matter is most likely made up of an entirely new elementary particle that would fall outside the Standard Model that all currently known particles fit into. It would interact only weakly with other known particles, making it very difficult to detect. There are two leading particles that theorists have postulated to describe the characteristics of dark matter: WIMPs and axions.

Weakly Interacting Massive Particles (WIMPs) would be electrically neutral and 100 to 1,000 times more massive than a proton. Axions would have no electric charge and be extraordinarily light – possibly as low as one-trillionth of the mass of an electron.

On the Hunt for Dark Matter

Not only does dark matter not emit light or electromagnetic radiation, it doesn't even interact with them. In fact, the only means by which scientists are confident dark matter interacts with ordinary matter is through gravity. That's why millions of dark matter particles pass through normal matter without anyone noticing. To capture even the tiniest glimpse, scientists are using some of the most sophisticated equipment in the world.

The Large Underground Xenon Experiment and Direct Detection

The Large Underground Xenon (LUX) experiment, which ran for nearly two years and ended in May 2016, was one of the most significant efforts to directly detect dark matter.

Directly detecting a dark matter particle requires it bump into a nucleus (the core of an atom) of ordinary matter. If this occurs, the nucleus would give off just a little bit of detectable energy. However, the probability of these particles colliding is staggeringly low.

In addition, Earth's surface has an extraordinary amount of radioactive "noise." Trying to detect dark matter interactions aboveground is like trying to hear someone whisper across the room of a noisy preschool.

To increase the chances of detecting a dark matter particle and only a dark matter particle, LUX was massive and located more than a mile underground. With a third of a ton of cooled liquid xenon surrounded by 72,000 gallons of water and powerful sensors, LUX had the world's best sensitivity for WIMPs. It could have detected a particle ranging in mass from a few times up to 1800 times the mass of a proton. Despite all of this, LUX never captured enough events to provide strong evidence of dark matter's presence.

LUX was what HEP calls a "Generation 1" direct detection experiment. Other "Generation 1" direct detection experiments currently running and supported by the Office of Science are taking a slightly different tack. The PICO 60, Darkside-50, and SuperCDMS-Soudanexperiments, for example, search for WIMPs, while the ADMX-2adetector hunted for the other potential dark matter candidate, the axion.

There are also "Generation 2" direct detection experiments currently in design, fabrication, or commissioning, including the LUX-Zeplin (LZ), Super CDMS-SNOLAB, and ADMX-Gen2.

The Alpha Magnetic Spectrometer and Indirect Detection

In addition, there are experiments focusing on indirect detection.

Some theorists propose that colliding dark matter particles could annihilate each other and produce two or more "normal" particles. In theory, colliding WIMPs could produce positrons. (A positron is the positively charged antimatter counterpart to the electron.) The Alpha Magnetic Spectrometer on the International Space Station captures cosmic rays, bits of atoms accelerated to high energies by exploding stars. If the AMS detects a high number of positrons in a high-energy spectrum where they wouldn't normally be, it could be a sign of dark matter.

"AMS is a beautiful instrument," said Salamon. "Everyone acknowledges this is the world's most high-precision cosmic-ray experiment in space."

So far, the AMS has recorded 25 billion events. It's found an excess of positrons within the appropriate range, but there's not enough evidence to state definitively where the positrons originate. There are other possible sources, such as pulsars.

In addition to the AMS, DOE also supports the Fermi Gamma-Ray Space Telescope, which analyzes gamma-rays as it circles the globe and may offer another route to dark matter detection.

Dark matter Production at the Large Hadron Collider

In theory, a particle accelerator could create dark matter by colliding standard particles at high energies. While the accelerator wouldn't be able to detect the dark matter itself, it could look for "missing" energy produced by such an interaction. Scientists at the Large Hadron Collider, the world's largest and most powerful particle accelerator, are taking this approach.

Lessons Learned and the Future of Research

So far, not a single experiment has yielded a definitive trace of dark matter.

But these experiments haven't failed – in fact, many have been quite successful. Instead, they've narrowed our field of search. Seeking dark matter is like looking for a lost item in your house. As you hunt through each room, you systematically eliminate places the object could be.

Instead of rooms, scientists are looking for dark matter across a range of interaction strengths and masses. "As experiments become more sensitive, we're starting to eliminate theoretical models," said Salamon.

The search for dark matter is far from over. With each bit of data, we come closer to understanding this ubiquitous yet elusive aspect of the universe. [16]

Latest dark matter searches leave scientists empty-handed

Scientists have lost their latest round of hide-and-seek with dark matter, but they're not out of the game.

Despite overwhelming evidence that an exotic form of matter lurks unseen in the cosmos, decades of searches have failed to definitively detect a single particle of dark matter. While some scientists continue down the road of increasingly larger detectors designed to catch the particles, others are beginning to consider a broader landscape of possibilities for what dark matter might be.

"We've been looking where our best guess told us to look for all these years, and we're starting to wonder if we maybe guessed wrong," says theoretical astrophysicist Dan Hooper of Fermilab in Batavia, Ill. "People are just opening their minds to a wider range of options."

Dark matter permeates the cosmos: The material keeps galaxies from flying apart and has left its imprints in the oldest light in the universe, the cosmic microwave background, which dates back to just 380,000 years after the Big Bang. Indirect evidence from dark matter's gravitational influences shows that it makes up the bulk of the mass in the universe. But scientists can't pin down what dark matter is without detecting it directly.

In new results published in August and September, three teams of scientists have come up empty-handed, finding no hints of dark matter. The trio of experiments searched for one particular variety of dark matter — hypothetical particles known as WIMPs, or weakly interacting massive particles, with a range of possible masses that starts at several times that of a proton. WIMPs, despite their name, are dark matter bigwigs — they have long been the favorite explanation for the universe's missing mass. WIMPs are thought to interact with normal matter only via the weak nuclear force and gravity.

Part of WIMPs' appeal comes from a prominent but unverified theory, supersymmetry, which independently predicts such particles. Supersymmetry posits that each known elementary particle has a heavier partner; the lightest partner particle could be a dark matter WIMP. But evidence for supersymmetry hasn't materialized in particle collisions at the Large Hadron Collider in Geneva, so supersymmetry's favored status is eroding (SN: 10/1/16, p. 12). Supersymmetry arguments for WIMPs are thus becoming shakier — especially since WIMPs aren't showing up in detectors.

Scientists typically search for WIMPs by looking for interactions with normal matter inside a detector. Several current experiments use tanks of liquefied xenon, an element found in trace amounts in Earth's atmosphere, in hopes of detecting the tiny amounts of light and electric charge that would be released when a WIMP strikes a xenon nucleus and causes it to recoil.

The three xenon experiments are the Large Underground Xenon, or LUX, experiment, located in the Sanford Underground Research Facility in Lead, S.D.; the PandaX-II experiment, located in China's JinPing underground laboratory in Sichuan; and the XENON100 experiment, located in the Gran Sasso National Laboratory in Italy. Teams of scientists at the three locations each reported no signs of dark matter particles. The experiments are most sensitive to particles with masses around 40 or 50 times that of a proton. Scientists can't completely rule out WIMPs of these masses, but the interactions would have to be exceedingly rare.

In initial searches, proponents of WIMPs expected that the particles would be easy to find. "It was thought to be like, 'OK, we'll run the detector for five minutes, discover dark matter, and we're all done,'" says physicist Matthew Szydagis of the University at Albany in New York, a member of LUX. That has turned into decades of hard work. As WIMPs keep failing to turn up, some scientists are beginning to become less enamored with the particles and are considering other possibilities more closely.

One alternative dark matter contender now attracting more attention is the axion. This particle was originally proposed decades ago as part of the solution to a particle physics quandary known as the strong CP problem — the question of why the strong nuclear force, which holds particles together inside the nucleus, treats matter and antimatter equally. If dark matter consists of axions, the particle could therefore solve two problems at once.

Axions are small fry as dark matter goes — they can be as tiny as a millionth of a billionth the mass of a WIMP. The particles interact so feebly that they are extremely difficult to detect. If axions are dark matter, "you're sitting in an enormous, dense sea of axions and you don't even notice them," says physicist Leslie Rosenberg of the University of Washington in Seattle, the leader of the Axion Dark Matter eXperiment. After a recent upgrade to the experiment, ADMX scientists are searching for dark matter axions using a magnetic field and special equipment to coax the particles to convert into photons, which can then be detected.

Although WIMPs and axions remain the front-runners, scientists are beginning to move beyond these two possibilities. In between the featherweight axions and hulking WIMPs lies a broad range of masses that hasn't been well explored. Scientists' favorite theories don't predict dark matter particles with such intermediate masses, says theoretical physicist Kathryn Zurek of Lawrence Berkeley National Laboratory in California, but that doesn't mean that dark matter couldn't be found there. Zurek advocates a diverse search over a broad range of masses, instead of focusing on one particular theory. "Dark matter direct detection is not one-size-fits-all," she says.

Nuclear recoil

Xenon dark matter experiments work by watching for dark matter interactions that cause xenon nuclei to recoil. Such interactions would theoretically release photons (orange lines) and electrons (red lines), which create two consecutive bursts of light that can be observed by light-detecting photomultiplier tubes (circles) at the top and bottom of the detector, as seen in this schematic of the LZ experiment.

In two papers published in Physical Review Letters on January 7 and September 14, Zurek and colleagues proposed using superconductors — materials that allow electricity to flow without resistance — and superfluids, which allow fluids to flow without friction, to detect light dark matter particles. "We are trying to broaden as much as possible the tools to search for dark matter," says Zurek. Likewise, scientists with the upcoming Super Cryogenic Dark Matter Search SNOLAB experiment, to be located in an underground lab in Sudbury, Canada, will use detectors made of germanium and silicon to search for dark matter with smaller masses than the xenon experiments can.

Scientists have not given up on xenon WIMP experiments. Soon some of those experiments will be scaling up — going from hundreds of kilograms of liquid xenon to tons — to improve their chances of catching a dark matter particle on the fly. The next version of XENON100, the XENON1T experiment (pronounced "XENON one ton") is nearly ready to begin taking data. LUX's next generation experiment, known as LUX-ZEPLIN or LZ, is scheduled to begin in 2020. PandaX-II scientists are also planning a sequel. Physicists are still optimistic that these detectors will finally find the elusive particles. "Maybe we will have some opportunity to see something nobody has seen," says Xiangdong Ji of Shanghai Jiao Tong University, the leader of PandaX-II. "That's what's so exciting."In the sea of nondetections of dark matter, there is one glaring exception. For years, scientists with the DAMA/LIBRA experiment at Gran Sasso have claimed to see signs of dark matter, using crystals of sodium iodide. But other experiments have found no signs of DAMA's dark matter. Many scientists believe that DAMA has been debunked. "I don't know what generates the weird signal that DAMA sees," says Hooper. "That being said, I don't think it's likely that it's dark matter."

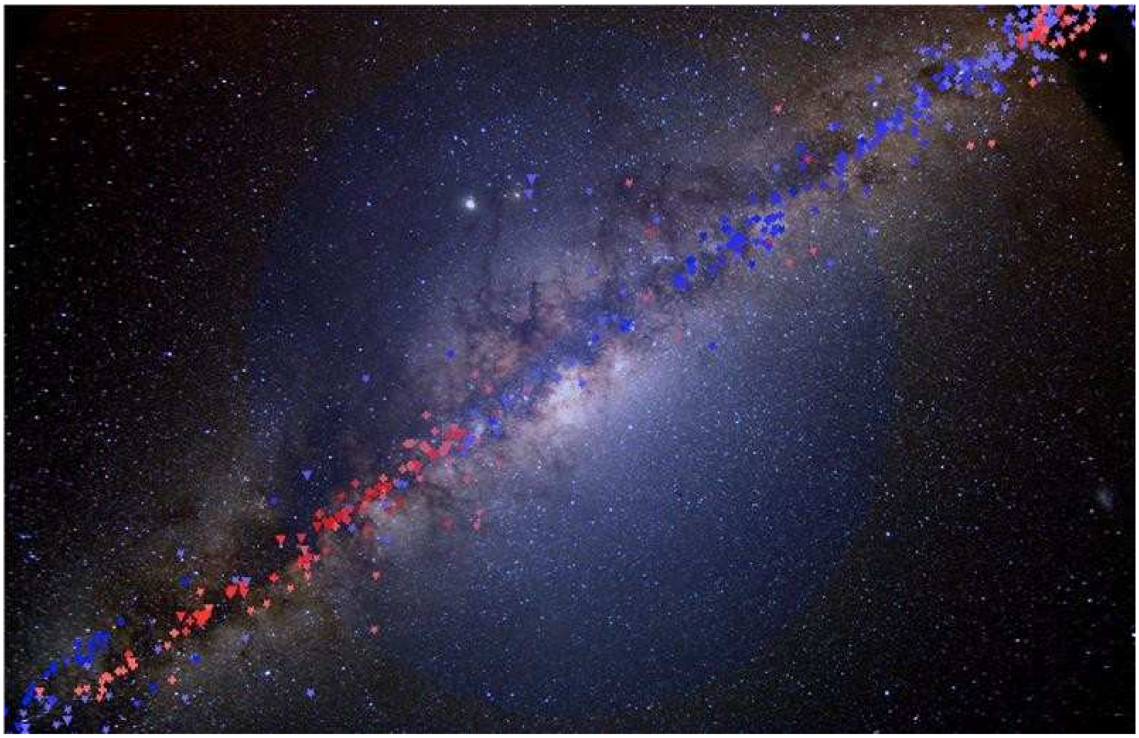
But other experiments have not used the same technology as DAMA, says theoretical astrophysicist Katherine Freese of the University of Michigan in Ann Arbor.

"There is no alternative explanation that anybody can think of, so that is why it is actually still very interesting." Three upcoming experiments should soon close the door on the mystery, by searching for dark matter using sodium iodide, as DAMA does: the ANAIS experiment in the Canfranc Underground Laboratory in Spain, the COSINE-100 experiment at YangYang Underground Laboratory in South Korea, and the SABRE experiment, planned for the Stawell Underground Physics Laboratory in Australia.

Scientists' efforts could still end up being for naught; dark matter may not be directly detectable at all. "It's possible that gravity is the only lens with which we can view dark matter," says Szydagis. Dark matter could interact only via gravity, not via the weak force or any other force. Or it could live in its own "hidden sector" of particles that interact among themselves, but mostly shun normal matter.

Even if no particles are detected anytime soon, most scientists remain convinced that an unseen form of matter exists. No alternative theory can explain all of scientists' cosmological observations. "The human being is not going to give up for a long, long time to try to search for dark matter, because it's such a big problem for us," says Ji. [15]

Evidence for dark matter in the inner Milky Way



The rotation curve tracers used in the paper over a photo of the disc of the Milky Way as seen from the Southern Hemisphere. The tracers are color-coded in blue or red according to their relative motion with respect to the Sun. The spherically symmetric blue halo illustrates the dark matter distribution.

The existence of dark matter in the outer parts of the Milky Way is well established. But historically it has proven very difficult to establish the presence of dark matter in the innermost regions, where the Solar System is located. This is due to the difficulty of measuring the rotation of gas and stars with the needed precision from our own position in the Milky Way.

“In our new study, we obtained for the first time a direct observational proof of the presence of dark matter in the innermost part of the Milky Way. We have created the most complete compilation so far of published measurements of the motion of gas and stars in the Milky Way, and compared the measured rotation speed with that expected under the assumption that only luminous matter exists in the Galaxy. The observed rotation cannot be explained unless large amounts of dark matter exist around us, and between us and the Galactic centre”, says Miguel Pato at the Department of Physics, Stockholm University.

Dark matter is about five times more abundant than the matter that we are familiar with, made of atoms. Its existence in galaxies was robustly established in the 1970s with a variety of techniques, including the measurement of the rotation speed of gas and stars, which provides a way to effectively “weigh” the host galaxy and determine its total mass.

“Our method will allow for upcoming astronomical observations to measure the distribution of dark matter in our Galaxy with unprecedented precision. This will permit to refine our understanding of the structure and evolution of our Galaxy, and it will trigger more robust predictions for the many experiments worldwide that search for dark matter particles. The study therefore constitutes a fundamental step forward in the quest for the nature of dark matter”, says Miguel Pato. [14]

Researchers may have uncovered a way to observe dark matter thanks to a discovery involving X-ray emissions.

Anyone with a passing knowledge of space and astronomy has heard of dark matter, a material believed to account for most of the known universe. We say "believed" because technically it hasn't been observed; the only reason we know it exists is because of gravitational effects on nearby objects, but otherwise it's completely invisible to light. But a major discovery this week suggests that invisibility doesn't extend to X-Ray emissions, which scientists may finally have used to detect dark matter in the universe.

It all happened when astronomers were reviewing data collected by the European Space Agency's XMM-Newton spacecraft and noticed a spike in X-Ray emissions. The anomaly came from two celestial objects - the Andromeda galaxy and Perseus galaxy cluster specifically - but didn't correspond to any known particle or atom. What the researchers did notice, however, was that it lined up perfectly with the theoretical behaviors of dark matter, allowing us to finally "see" it for the first time.

"With the goal of verifying our findings," said Alexey Boyarsky of Switzerland's École Polytechnique Fédérale de Lausanne, "we then looked at data from our own galaxy, the Milky Way, and made the same observations."

If the EPFL's findings hold up, this has huge implications for future astronomy research. Our current picture of space accounts for dark matter tangentially since we can't actually see it. But Boyarksy thinks it might be possible to develop technology to observe it directly, which could vastly change our perceptions of outer space.

"Confirmation of this discovery may lead to construction of new telescopes specially designed for studying the signals from dark matter particles," Boyarsky explain. "We will know where to look in order to trace dark structures in space and will be able to reconstruct how the universe has formed."

That also sounds handy if we ever get warp technology off the ground and need to chart a path around dark matter, but I'm probably getting ahead of myself on that score. [13]

New revelations on dark matter and relic neutrinos

The Planck collaboration, which notably includes the CNRS, CEA, CNES and several French universities, has disclosed, at a conference in Ferrara, Italy, the results of four years of observations from the ESA's Planck satellite. The satellite aims to study relic radiation (the most ancient light in the Universe). This light has been measured precisely across the entire sky for the first time, in both intensity and polarization, thereby producing the oldest image of the Universe. This primordial light lets us "see" some of the most elusive particles in the Universe: dark matter and relic neutrinos.

Between 2009 and 2013, the Planck satellite observed relic radiation, sometimes called cosmic microwave background (CMB) radiation. Today, with a full analysis of the data, the quality of the map is now such that the imprints left by dark matter and relic neutrinos are clearly visible.

Already in 2013, the map for variations in light intensity was released, showing where matter was in the sky 380,000 years after the Big Bang. Thanks to the measurement of the polarization of this light (in four of seven frequencies, for the moment), Planck can now see how this material used to move. Our vision of the primordial Universe has thus become dynamic. This new dimension, and the quality of the data, allows us to test numerous aspects of the standard model of cosmology. In particular, they illuminate the most elusive of particles: dark matter and neutrinos.

New constraints on dark matter

The Planck collaboration results now make it possible to rule out an entire class of models of dark matter, in which dark matter-antimatter annihilation is important. Annihilation is the process whereby a particle and its antiparticle jointly disappear, followed by a release in energy.

The basic existence of dark matter is becoming firmly established, but the nature of dark matter particles remains unknown. There are numerous hypotheses concerning the physical nature of this matter, and one of today's goals is to whittle down the possibilities, for instance by searching for the effects of this mysterious matter on ordinary matter and light. Observations made by Planck show that it is not necessary to appeal to the existence of strong dark matter-antimatter annihilation to explain the dynamics of the early universe. Such events would have produced enough energy to exert an influence on the evolution of the light-matter fluid in the early universe, especially around the time relic radiation was emitted. However, the most recent observations show no hints that this actually took place.

These new results are even more interesting when compared with measurements made by other instruments. The satellites Fermi and Pamela, as well as the AMS-02 experiment aboard the International Space Station, have all observed an excess of cosmic rays, which might be interpreted as a consequence of dark matter annihilation. Given the Planck observations, however, an alternative explanation for these AMS-02 or Fermi measurements—such as radiation from undetected pulsars—has to be considered, if one is to make the reasonable hypothesis that the properties of dark matter particles are stable over time.

Additionally, the Planck collaboration has confirmed that dark matter comprises a bit more than 26% of the Universe today (figure deriving from its 2013 analysis), and has made more accurate maps of the density of matter a few billion years after the Big Bang, thanks to measurements of temperature and B-mode polarization.

Neutrinos from the earliest instants detected

The new results from the Planck collaboration also inform us about another type of very elusive particle, the neutrino. These "ghost" particles, abundantly produced in our Sun for example, can pass through our planet with almost no interaction, which makes them very difficult to detect. It is therefore not realistic to directly detect the first neutrinos, which were created within the first second after the Big Bang, and which have very little energy. However, for the first time, Planck has unambiguously detected the effect these relic neutrinos have on relic radiation maps.

The relic neutrinos detected by Planck were released about one second after the Big Bang, when the Universe was still opaque to light but already transparent to these particles, which can freely escape from environments that are opaque to photons, such as the Sun's core. 380,000 years later, when relic radiation was released, it bore the imprint of neutrinos because photons had gravitational interaction with these particles. Observing the oldest photons thus made it possible to confirm the properties of neutrinos.

Planck observations are consistent with the standard model of particle physics. They essentially exclude the existence of a fourth species of neutrinos, previously considered a possibility based on the final data from the WMAP satellite, the US predecessor of Planck. Finally, Planck makes it possible to set an upper limit to the sum of the mass of neutrinos, currently established at 0.23 eV (electron-volt).

The full data set for the mission, along with associated articles that will be submitted to the journal Astronomy & Astrophysics (A&A), will be available December 22 on the ESA web site. [12]

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!?

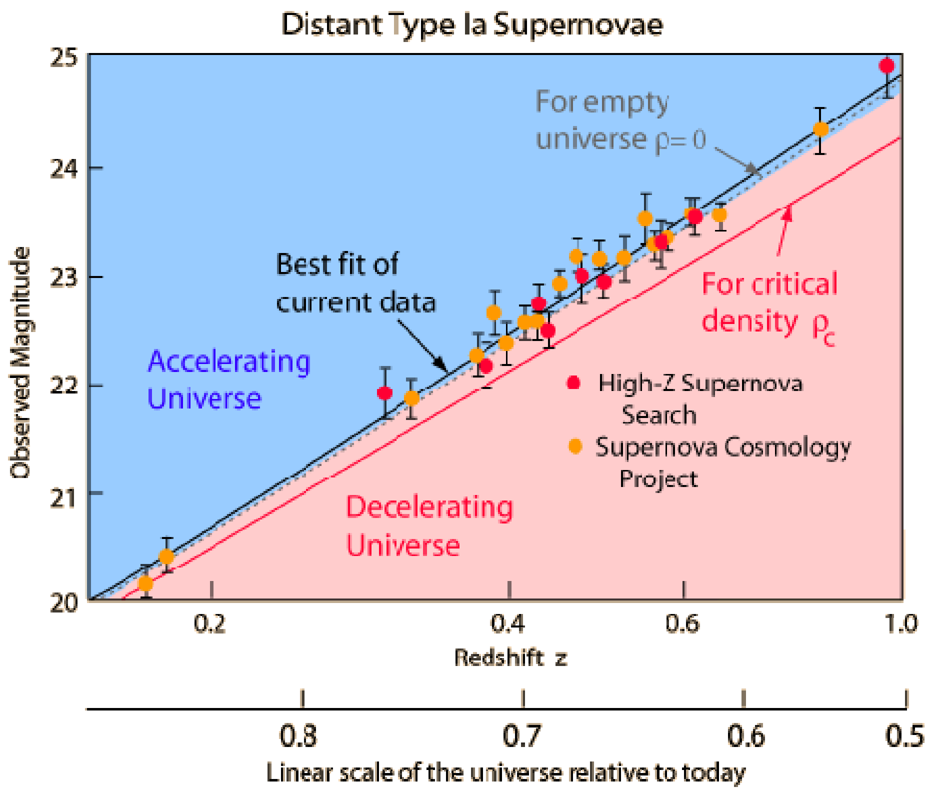
The gravitational force attracting the matter, causing concentration of the matter in a small space and leaving much space with low matter concentration: dark matter and energy.

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.

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 1a supernovae around z=.6, which with a Hubble constant of 71 km/s/mpc 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

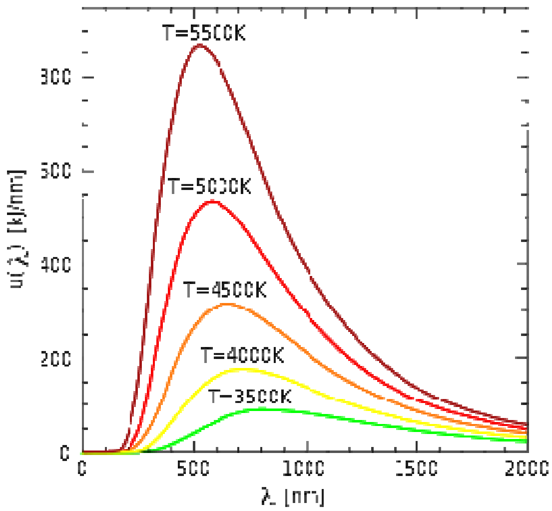
Dark matter is a type of matter hypothesized in astronomy and cosmology to account for a large part of the mass that appears to be missing from the universe. Dark matter cannot be seen directly with telescopes; evidently it neither emits nor absorbs light or other electromagnetic radiation at any significant 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 **A** vector potential experienced by the electrons moving by **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 **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_o inertial mass is the result of the spin, since this is the only accelerating motion of the electric charge. Since the accelerating motion has different frequency for the electron in the atom and the proton, they masses are different, also as the wavelengths on both sides of the diffraction pattern, giving equal intensity of radiation.

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

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.

The Weak Interaction

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

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

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

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

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

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

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

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

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

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

The General Weak Interaction

The Weak Interactions T-asymmetry is in conjunction with the T-asymmetry of the Second Law of Thermodynamics, meaning that locally lowering entropy (on extremely high temperature) causes for example the Hydrogen fusion. The arrow of time by the Second Law of Thermodynamics shows the increasing entropy and decreasing information by the Weak Interaction, changing the temperature dependent diffraction patterns. A good example of this is the neutron decay, creating more particles with less known information about them.

The neutrino oscillation of the Weak Interaction shows that it is a general electric dipole change and it is possible to any other temperature dependent entropy and information changing diffraction pattern of atoms, molecules and even complicated biological living structures.
We can generalize the weak interaction on all of the decaying matter constructions, even on the biological too. This gives the limited lifetime for the biological constructions also by the arrow of time. There should be a new research space of the Quantum Information Science the 'general neutrino oscillation' for the greater then subatomic matter structures as an electric dipole change.
There is also connection between statistical physics and evolutionary biology, since the arrow of time is working in the biological evolution also.
The Fluctuation Theorem says that there is a probability that entropy will flow in a direction opposite to that dictated by the Second Law of Thermodynamics. In this case the Information is growing that is the matter formulas are emerging from the chaos. So the Weak Interaction has two directions, samples for one direction is the Neutron decay, and Hydrogen fusion is the opposite direction.

The Sterile Neutrino

By definition the sterile neutrino does not participate in the electromagnetic and weak interactions, only the gravitational force gives its mass. There should be one strange neutrino that changes the diffraction patterns of the electromagnetic oscillations leaving the low frequencies side of the Planck Distribution Law with non-compensated high frequency side. Since the neutrino oscillation and the general weak interaction this sterile neutrino can be oscillate to another measurable neutrino.

The change of the temperature at the Big Bang was the main source for this asymmetry and the creation of the dark matter by the Baryogenesis.[10] Later on also the weak interaction can change the rate of the dark matter, but less influencing it, see the temperature changes of the dark side in the Planck Distribution Law.

The Weak Interaction basically an electric dipole change and transferring the electric charge from one side of the diffraction pattern to the other side. If there is no other side (dark matter), the neutrino oscillation helps to change the frequency of the electromagnetic oscillations, causing real diffraction patterns and leaving the non – compensated side of the Planck Distribution curve for the invisible 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 Bing Bang caused parallel moving of the matter gives this magnetic force, experienced as gravitational force.

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

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

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

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

The 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

A new study is providing evidence for the presence of dark matter in the innermost part of the Milky Way, including in our own cosmic neighborhood and the Earth's location. The study demonstrates that large amounts of dark matter exist around us, and also between us and the Galactic centre. The result constitutes a fundamental step forward in the quest for the nature of dark matter. [14]
If the EPFL's findings hold up, this has huge implications for future astronomy research. Our current picture of space accounts for dark matter tangentially since we can't actually see it. But Boyarksy thinks it might be possible to develop technology to observe it directly, which could vastly change our perceptions of outer space. [13]
Between 2009 and 2013, the Planck satellite observed relic radiation, sometimes called cosmic microwave background (CMB) radiation. Today, with a full analysis of the data, the quality of the map is now such that the imprints left by dark matter and relic neutrinos are clearly visible. [12]
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] The sterile neutrino [11] disappears in the neutrino oscillation.

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