# Dark Gauge Bosons

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*The PICO bubble chambers use temperature and sound to tune into dark matter particles. [24]*

*A detection device designed and built at Yale is narrowing the search for dark matter in the form of axions, a theorized subatomic particle that may make up as much as 80% of the matter in the universe. [23]*

*The race is on to build the most sensitive U.S.-based experiment designed to directly detect dark matter particles. Department of Energy officials have formally approved a key construction milestone that will propel the project toward its April 2020 goal for completion. [22]*

*Scientists at the Center for Axion and Precision Physics Research (CAPP), within the Institute for Basic Science (IBS) have optimized some of the characteristics of a magnet to hunt for one possible component of dark matter called axion. [21]*

*The first sighting of clustered dwarf galaxies bolsters a leading theory about how big galaxies such as our Milky Way are formed, and how dark matter binds them, researchers said Monday. [20]*

*Invisible Dark Force of the Universe --"CERN's NA64 Zeroing in on Evidence of Its Existence" [19]*

*Scientists from The University of Manchester working on a revolutionary telescope project have harnessed the power of distributed computing from the UK's GridPP collaboration to tackle one of the Universe's biggest mysteries – the nature of dark matter and dark energy. [18]*

*In the search for the mysterious dark matter, physicists have used elaborate computer calculations to come up with an outline of the particles of this unknown form of matter. [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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Author: George Rajna

## Search for Dark Gauge Bosons Decaying into Displaced Lepton-Jets in Proton-Proton Collisions at s=13 TeV with the ATLAS Detector

The dark photon (A'), the gauge boson carrier of a hypothetical new force, has been proposed in a wide range of Beyond the Standard Model (BSM) theories, and could serve as our window to an entire dark sector. A massive A' could decay back to the SM with a significant branching fraction, through kinetic mixing with the SM photon. If this A' can be produced from decays of a dark scalar that mixes with the SM Higgs, collider searches involving leptonic final states provide promising discovery prospects with rich phenomenology. This work presents the results of a search in 2015 ATLAS data for A's in the mass range of 0.2 to 10 GeV decaying into collimated jets of light leptons and mesons, so-called "lepton-jets". No deviations from SM expectations are observed. Limits on benchmark models predicting Higgs decays to A's are derived as a function of the A' lifetime; limits are also established in the parameter space of A' mass vs kinetic mixing. Complementary to various other ATLAS A' searches, lepton-jet analyses will continue to expand in model coverage and in parameter space as data-taking continues at the LHC. [26]

## Dark matter detection receives 10-ton upgrade

In an abandoned gold mine one mile beneath Lead, South Dakota, the cosmos quiets down enough to potentially hear the faint whispers of the universe's most elusive material—dark matter.

Shielded from the deluge of cosmic rays constantly showering the Earth's surface, and scrubbed of noisy radioactive metals and gasses, the mine, scientists think, will be the ideal setting for the most sensitive dark matter experiment to date. Known as LUX-ZEPLIN, the experiment will launch in 2020 and will listen for a rare collision between a dark matter particle with 10 tons of liquid xenon.

Ten University of Wisconsin–Madison scientists are involved in designing and testing the detector, and are part of a team of more than 200 researchers from 38 institutions in five countries working on the project. This month, the Department of Energy approved proceeding with the final stages of assembly and construction of LZ at the Sanford Underground Research Facility in South Dakota, with a total project cost of $55 million. Additional support comes from international collaborators in the United Kingdom, South Korea and Portugal, as well as the South Dakota Science and Technology Authority. The researchers' goal is to take the experiment online as quickly as possible to compete in a global race to be the first to detect dark matter.

In the 1930s, as astronomers studied the rotation of distant galaxies, they noticed that there wasn't enough matter—stars, planets, hot gas—to hold the galaxies together through gravity. There had to be some extra mass that helped bind all the visible material together, but it was invisible, missing.

Dark matter, scientists believe, comprises that missing mass, contributing a powerful gravitational counterbalance that keeps galaxies from flying apart. Although dark matter has so far proven to be undetectable, there may be a lot of it—about five times more than regular matter.

"Dark matter particles could be right here in the room streaming through your head, perhaps occasionally running into one of your atoms," says Duncan Carlsmith, a professor of physics at UW–Madison.

One proposed explanation for dark matter is weakly interacting massive particles, or WIMPs, particles that usually pass undetected through normal matter but which may, on occasion, bump into it. The LZ experiment, and similar projects in Italy and China, are designed to detect—or rule out—WIMPs in the search to explain this ghostly material.

The detector is set up like an enormous bell capable of ringing in response to the lightest tap from a dark matter particle. Nestled within two outer chambers designed to detect and remove contaminating particles lies a chamber filled with 10 tons of liquid xenon. If a piece of dark matter runs into a xenon atom, the xenon will collide with its neighbors, producing a burst of ultraviolet light and releasing electrons.

Moments later, the free electrons will excite the xenon gas at the top of the chamber and release a second, brighter burst of light. More than 500 photomultiplier tubes will watch for these signals, which together can discriminate between a contaminating particle and true dark matter collisions.

Kimberly Palladino, an assistant professor of physics at UW–Madison, and graduate student Shaun Alsum were part of the research team for LUX, the predecessor to LZ, which set records searching for WIMPs. Building on their experience from the previous experiment, Palladino, Alsum, graduate student Jonathan Nikoleyczik and undergraduate researchers are conducting simulations of dark matter collisions and prototyping the particle detector to increase the sensitivity of LZ and more stringently discard signals produced by ordinary matter.

The LZ project is "doing science the way you want to do science," says Palladino, explaining how the collaboration provides the time, funding and expertise needed to address fundamental questions about the nature of the universe.

The success of LZ depends in part on excluding contaminating materials, including reactive chemicals and trace amounts of radioactive elements, from the xenon, which relies on engineering prowess provided by UW–Madison's Physical Sciences Laboratory. Jeff Cherwinka, chief engineer of the LZ project and a PSL mechanical engineer, is overseeing assembly of the dark matter detector in a special facility scrubbed of radioactive radon and is designing a system to continuously remove gas that leaches out of the xenon chamber lining. Together with PSL engineer Terry Benson, Cherwinka is also designing the xenon storage system to prevent any radioactive elements from leaking in during transport and installation.

"It's one of the strengths of the university that we have the engineering and manufacturing expertise to contribute to these big-scale projects," says Cherwinka. "It helps UW gain more stake in these projects."

Meanwhile, Carlsmith and Sridhara Dasu, also a UW–Madison professor of physics, are designing computational systems to manage and analyze the data coming out of the detector in order to be ready to listen for dark matter collisions as soon as LZ is turned on in 2020. Once operational, LZ will quickly approach the fundamental limit of its detection capacity, the background noise of particles streaming out of the sun.

"In a year, if there are no WIMPs, or if they interact too weakly, we'll see nothing," says Carlsmith. The experiment is expected to operate for at least five years to confirm any initial observations and set new limits on potential interactions between WIMPs and ordinary matter.

Other experiments, including Wisconsin IceCube Particle Astrophysics Center projects IceCube, HAWC, and CTA, are searching for the signatures of dark matter annihilation events as independent and indirect methods to investigate the nature of dark matter. In addition, UW–Madison scientists are working at the Large Hadron Collider, searching for evidence that dark matter is produced during high energy particle collisions. This combination of efforts provides the best opportunity yet for uncovering more about the nature of dark matter, and with it the evolution and structure of our universe. [25]

## PICO dark matter detector more sensitive than expected

Although invisible to our telescopes, dark matter is known by its gravitational effects throughout the universe. The nature of dark matter is unknown, but the consensus of the astrophysics and particle physics communities is that the dark matter is composed of new fundamental particles, associated with an unknown area of physics. To detect this dark matter, scientists are using instruments called bubble chambers, among other strategies. And now a team has made one that has the world's best sensitivity to date, coming in at 17 times that of its most recent predecessor.

"This sensitivity means we can build a larger detector and run it longer with the expectation that there will not be background from other types of radiation," said David Asner, Chief Scientist for particle physics at Department of Energy's Pacific Northwest National Laboratory and a member of the PICO Collaboration.

Because physicists can't "see" dark matter, they need to find something that will alert them if dark matter bumps into it, sort of how a motion-sensitive alarm screeches when moved. Bubble chambers do this. Filled with a liquid kept just below its boiling temperature, bubbles erupt when a tiny particle with just enough energy hits the chamber. And physicists know little about dark matter, so they are searching for a variety of possible forms. Members of the PICO science team are looking for a particular type called spin-dependent WIMPs. The highly sensitive bubble chamber is filled with a fluorine-containing liquid that responds by forming a bubble when a neutron from certain types of radiation plows through. They theorize that if—or when—one of these WIMPs does so, the bubble chamber will also detect this dark matter particle.

"We don't know the nature of dark matter interactions with regular matter. PICO provides a unique probe and opportunity for discovery," said Asner. [24]

## Searching for axion dark matter with a new detection device

A detection device designed and built at Yale is narrowing the search for dark matter in the form of axions, a theorized subatomic particle that may make up as much as 80% of the matter in the universe.

Led by Yale physicist Steve Lamoreaux, a team of scientists announced the first results of the project, called Haloscope At Yale Sensitive To Axion Cold Dark Matter (HAYSTAC). The findings appear in the journal Physical Review Letters.

"The existence of dark matter has been established with a high degree of confidence. However at present nobody knows what it is, and it remains among the outstanding questions of modern science," said Lamoreaux. "Our work is setting important limits on a leading dark matter theory."

That theory centers on the axion, a particle that was proposed in the 1980s. Lamoreaux said the axion—which has no charge, no spin, and a miniscule amount of mass—has all of the necessary properties to be a compelling dark matter candidate. The observed dark matter density in our galaxy requires roughly 10 trillion axions per cubic centimeter; however, their direct interactions with ordinary matter are so feeble that their detection requires extremely sensitive experimental techniques.

Using a new instrument built at Yale's Wright Lab, Lamoreaux and his colleagues widened the possible parameters for detecting axions. Their study demonstrates the instrument sensitivity required to detect axions that are 10 times heavier than those targeted by previous experiments.

Axion detectors use intense magnetic fields to convert axions into detectable microwave photons at a specific frequency determined by the unknown axion mass. Previous experiments have searched for low-mass axions. Pushing the search to higher masses has been challenging for scientists because it requires high-frequency detectors that are physically smaller, and the signals from axion conversion in such cases is weaker.

"Our major breakthrough was making the detector colder and quieter than ever before, by adapting amplifiers developed for quantum computing research whose noise performance approaches the fundamental limits imposed by the laws of quantum mechanics," Lamoreaux said. "With the first data from our detector, we have set limits on the interactions of dark matter axions and opened a new portion of the allowed axion mass range to experimental investigation."

The first author of the paper is Ben Brubaker, a graduate student in the Lamoreaux lab at Yale. Additional Yale co-authors are Ling Zhong, Yulia Gurevich, Sidney Cahn, and Kelly Backes. Other co-authors are from the University of California-Berkeley, the University of Colorado, the National Institute of Standards and Technology, and Lawrence Livermore National Laboratory.

"The axion dark matter experiment at Yale pushes the frontiers of particle astrophysics," said Karsten Heeger, director of the Wright Laboratory. "It is a shining example of a university-based experiment that uses cutting edge instrumentation and leverages local infrastructure to address one of the fundamental questions about the universe and train the next generation of scientists. We are excited to have such a world-leading effort here on campus at the Wright Lab." [23]

## Next-gen dark matter detector in a race to finish line

The race is on to build the most sensitive U.S.-based experiment designed to directly detect dark matter particles. Department of Energy officials have formally approved a key construction milestone that will propel the project toward its April 2020 goal for completion.

The LUX-ZEPLIN (LZ) experiment, which will be built nearly a mile underground at the Sanford Underground Research Facility (SURF) in Lead, S.D., is considered one of the best bets yet to determine whether theorized dark matter particles known as WIMPs (weakly interacting massive particles) actually exist. There are other dark matter candidates, too, such as "axions" or "sterile neutrinos," which other experiments are better suited to root out or rule out.

The fast-moving schedule for LZ will help the U.S. stay competitive with similar next-gen dark matter direct-detection experiments planned in Italy and China.

On Feb. 9, the project passed a DOE review and approval stage known as Critical Decision 3 (CD-3), which accepts the final design and formally launches construction.

"We will try to go as fast as we can to have everything completed by April 2020," said Murdock "Gil" Gilchriese, LZ project director and a physicist at the DOE's Lawrence Berkeley National Laboratory (Berkeley Lab), the lead lab for the project. "We got a very strong endorsement to go fast and to be first." The LZ collaboration now has about 220 participating scientists and engineers who represent 38 institutions around the globe.

The nature of dark matter—which physicists describe as the invisible component or so-called "missing mass" in the universe that would explain the faster-than-expected spins of galaxies, and their motion in clusters observed across the universe—has eluded scientists since its existence was deduced through calculations by Swiss astronomer Fritz Zwicky in 1933.

The quest to find out what dark matter is made of, or to learn whether it can be explained by tweaking the known laws of physics in new ways, is considered one of the most pressing questions in particle physics.

Successive generations of experiments have evolved to provide extreme sensitivity in the search that will at least rule out some of the likely candidates and hiding spots for dark matter, or may lead to a discovery.

LZ will be at least 50 times more sensitive to finding signals from dark matter particles than its predecessor, the Large Underground Xenon experiment (LUX), which was removed from SURF last year to make way for LZ. The new experiment will use 10 metric tons of ultra-purified liquid xenon, to tease out possible dark matter signals. Xenon, in its gas form, is one of the rarest elements in Earth's atmosphere.

"The science is highly compelling, so it's being pursued by physicists all over the world," said Carter Hall, the spokesperson for the LZ collaboration and an associate professor of physics at the University of Maryland. "It's a friendly and healthy competition, with a major discovery possibly at stake."

A planned upgrade to the current XENON1T experiment at National Institute for Nuclear Physics' Gran Sasso Laboratory (the XENONnT experiment) in Italy, and China's plans to advance the work on PandaX-II, are also slated to be leading-edge underground experiments that will use liquid xenon as the medium to seek out a dark matter signal. Both of these projects are expected to have a similar schedule and scale to LZ, though LZ participants are aiming to achieve a higher sensitivity to dark matter than these other contenders.

Hall noted that while WIMPs are a primary target for LZ and its competitors, LZ's explorations into uncharted territory could lead to a variety of surprising discoveries. "People are developing all sorts of models to explain dark matter," he said. "LZ is optimized to observe a heavy WIMP, but it's sensitive to some less-conventional scenarios as well. It can also search for other exotic particles and rare processes."

LZ is designed so that if a dark matter particle collides with a xenon atom, it will produce a prompt flash of light followed by a second flash of light when the electrons produced in the liquid xenon chamber drift to its top. The light pulses, picked up by a series of about 500 light-amplifying tubes lining the massive tank—over four times more than were installed in LUX—will carry the telltale fingerprint of the particles that created them.

Daniel Akerib, Thomas Shutt, and Maria Elena Monzani are leading the LZ team at SLAC National Accelerator Laboratory. The SLAC effort includes a program to purify xenon for LZ by removing krypton, an element that is typically found in trace amounts with xenon after standard refinement processes. "We have already demonstrated the purification required for LZ and are now working on ways to further purify the xenon to extend the science reach of LZ," Akerib said.

SLAC and Berkeley Lab collaborators are also developing and testing hand-woven wire grids that draw out electrical signals produced by particle interactions in the liquid xenon tank. Full-size prototypes will be operated later this year at a SLAC test platform. "These tests are important to ensure that the grids don't produce low-level electrical discharge when operated at high voltage, since the discharge could swamp a faint signal from dark matter," said Shutt.

Hugh Lippincott, a Wilson Fellow at Fermi National Accelerator Laboratory (Fermilab) and the physics coordinator for the LZ collaboration, said, "Alongside the effort to get the detector built and taking data as fast as we can, we're also building up our simulation and data analysis tools so that we can understand what we'll see when the detector turns on. We want to be ready for physics as soon as the first flash of light appears in the xenon." Fermilab is responsible for implementing key parts of the critical system that handles, purifies, and cools the xenon.

All of the components for LZ are painstakingly measured for naturally occurring radiation levels to account for possible false signals coming from the components themselves. A dust-filtering cleanroom is being prepared for LZ's assembly and a radon-reduction building is under construction at the South Dakota site—radon is a naturally occurring radioactive gas that could interfere with dark matter detection. These steps are necessary to remove background signals as much as possible.

The vessels that will surround the liquid xenon, which are the responsibility of the U.K. participants of the collaboration, are now being assembled in Italy. They will be built with the world's most ultra-pure titanium to further reduce background noise.

To ensure unwanted particles are not misread as dark matter signals, LZ's liquid xenon chamber will be surrounded by another liquid-filled tank and a separate array of photomultiplier tubes that can measure other particles and largely veto false signals. Brookhaven National Laboratory is handling the production of another very pure liquid, known as a scintillator fluid, that will go into this tank.

The cleanrooms will be in place by June, Gilchriese said, and preparation of the cavern where LZ will be housed is underway at SURF. Onsite assembly and installation will begin in 2018, he added, and all of the xenon needed for the project has either already been delivered or is under contract. Xenon gas, which is costly to produce, is used in lighting, medical imaging and anesthesia, space-vehicle propulsion systems, and the electronics industry.

"South Dakota is proud to host the LZ experiment at SURF and to contribute 80 percent of the xenon for LZ," said Mike Headley, executive director of the South Dakota Science and Technology Authority (SDSTA) that oversees SURF. "Our facility work is underway and we're on track to support LZ's timeline."

UK scientists, who make up about one-quarter of the LZ collaboration, are contributing hardware for most subsystems. Henrique Araújo, from Imperial College London, said, "We are looking forward to seeing everything come together after a long period of design and planning."

Kelly Hanzel, LZ project manager and a Berkeley Lab mechanical engineer, added, "We have an excellent collaboration and team of engineers who are dedicated to the science and success of the project." The latest approval milestone, she said, "is probably the most significant step so far," as it provides for the purchase of most of the major components in LZ's supporting systems. [22]

## "Breakthrough?" --Magnetic Fields May Reveal Evidence of Dark Matter

Dark matter is needed to explain the motions of galaxies and some of the current theories of galaxy formation and evolution. For example, the galaxy that contains our solar system, the Milky Way, seems to be enveloped by a much larger halo of dark matter. Its halo is quite different from the one we draw behind angels; it is actually invisible, but its existence is inferred through its effects on the motions of stars and gases.

Scientists at the Center for Axion and Precision Physics Research (CAPP), within the Institute for Basic Science (IBS) have optimized some of the characteristics of a magnet to hunt for one possible component of dark matter called axion.

Although it sounds hard to believe, everything we see with our naked eyes or through microscopes and telescopes accounts for just 4% of the known Universe. The rest comprises dark energy (69%) and dark matter (27%). Although there seems to be more dark matter than visible matter in the Universe, we still have not been able to directly detect it. The reason is that dark matter does not emit light or absorb electromagnetic waves, so it is really hard to observe.

Although dark matter particles have not been detected so far, scientists know that these particles have a very small mass and are distributed throughout the Universe. One dark matter particle candidate is the axion. Axions have extremely weak interactions with matter and so scientists need special equipment to catch their presence. Specifically, scientists use the so-called axion to two-photons coupling technique, which takes advantage of the fact that an axion passing through a strong magnetic field can interact with a photon and convert into another photon. To record this interaction, IBS scientists are in the process of building haloscopes in Daejeon in South Korea.

Haloscopes contain resonant cavities immersed in extra-strong magnetic field. "In simple terms, you can image the resonant cavity as a cylinder, like a soft drink can, where the energy of the photons generated from the axions-photons interaction is amplified," explains KO Byeong Rok, first author of this study.

The magnets used for these types of experiments so far have the shape of a coil wound into a helix, technically known as a solenoid. However, depending on the height of the magnet, there is the risk of losing the signal coming from the axion-photon interaction. For this reason, IBS scientists decided to look deeper into another type of magnets shaped like donuts, called toroidal magnets.

"Magnets are the most important feature of the haloscope, and also the most expensive. While other experiments seeking to detect dark matter around the world use solenoid magnets, we are the first to try to use toroidal magnets. Since it has never been used before, you cannot easily buy the equipment, so we develop it ourselves," explains Professor Ko.

In order to hunt the axion, scientists need to get out in front of it, and predict the magnitude of the electromagnetic energy expected from the axion-to-photon conversion. Electromagnetic energy is due to the sum of electric and magnetic energies. Both of them can be easily calculated for a solenoid magnet, but if the magnet is toroidal shaped, it is practically impossible to calculate the magnetic energy analytically. Because of this, it was believed that toroidal magnets could not be used for the haloscope.

This paper from IBS shows the opposite. Starting from an adjusted version of the Maxwell equation, which defines how charged particles give rise to electric and magnetic forces. Scientists found that electric energy and magnetic energy from the axion-photon interaction are equal in both types of magnets. Therefore, even though the magnetic energy of a toroidal magnet is unknown, in order to obtain the electromagnetic energy which is the sum of the two, it is possible to double up the electric energy and obtain the magnetic energy.

Another finding is that the energy emitted from the interaction and conversion of the axion to photon is independent from the position of the cavity inside a solenoid magnet. However, this is not the case for toroid magnets.

IBS CAPP scientists have nicknamed the toroidal cavity "CAPPuccino submarine" because its color resembles the beverage, and its particular shape. All the theoretical findings published in this paper are going to form a solid background for the development and prototyping of new machines for the search of dark matter. [21]

## Dwarf galaxies shed light on dark matter

The first sighting of clustered dwarf galaxies bolsters a leading theory about how big galaxies such as our Milky Way are formed, and how dark matter binds them, researchers said Monday.

Theorised but never seen, the bundled galaxies were discovered using the largest optical survey of the night sky ever compiled, they reported in the journal Nature Astronomy.

Seven clusters of three-to-five galaxies are each 10 to 1,000 times smaller than the Milky Way.

Unlike our home galaxy, all have long-since stopped giving birth to new stars.

"We suspect these groups are gravitationally bound and thus will eventually merge to form one larger, intermediate-mass galaxy," said lead author Sabrina Stierwalt, an astrophysicist at the National Radio Astronomy Observatory in Charlotteville, Virginia.

The findings shed light on several big questions about how structures such as galaxies formed in the early Universe, she told AFP.

A leading theory predicts that, after the Big Bang some 13.7 billion years ago, smaller things joined together to form bigger ones.

But there has been frustratingly little observational evidence of such mergers occurring on a scale as small as dwarf galaxies, Stierwalt explained.

One reason is that dwarf galaxies are hard to see. Only two—known at the Magellanic Clouds—are visible to the naked eye.

As of a decade ago, no more than a dozen had been identified by astronomers.

And even as bigger telescopes made their discovery commonplace, those found were either isolated "field dwarfs," or "satellite dwarfs" being cannibalised by larger galaxies.

"Independent groups of only low-mass galaxies—like the ones we found—reveal a possible formation mechanism for larger ones such as our Milky Way," Stierwalt said.

The clusters are between 200 million and 650 million light years away from Earth.

"That sounds like a lot, but it is relatively nearby given the vast size of the Universe," she said.

### Hunting dark matter

The researchers spotted the galaxies by combing through a massive library of star maps compiled under a project known as the Sloan Digital Sky Survey, made public in 2008 and upgraded regularly since.

The team then used telescopes—including one at the Apache Point Observatory in New Mexico, and the Walter Baade Telescope at the Los Campanas Observatory in Chile—to confirm their findings.

Dwarf clusters are also natural laboratories for better understanding the mysterious substance known as dark matter, thought to account for a quarter of the Universe, the study found.

Likely made up of unknown sub-atomic particles, dark matter can only be inferred through its gravitational pull on other objects in space.

Visible matter—everything we can touch and see—comprises about five percent of the Universe.

Dwarf galaxies are doubly interesting in the quest to understand dark matter.

Compared to larger galaxies, "they tend to have a lot more dark matter," explained Stierwalt.

Its gravitational force holds the clusters together.

And because they are older, these dwarf galaxies also have very little "debris" such as gas and dust, and thus are unobstructed hunting grounds for dark matter.

Some astronomers are searching for this elusive substance using gamma-ray detecting telescopes, on the theory that dark matter particles may produce gamma rays as they decay or annihilate each other in space. [20]

## Invisible Dark Force of the Universe --"CERN's NA64 Zeroing in on Evidence of Its Existence"

One of the biggest puzzles in physics is that eighty-five percent of the matter in our universe is "dark": it does not interact with the photons of the conventional electromagnetic force and is therefore invisible to our eyes and telescopes. Although the composition and origin of dark matter are a mystery, we know it exists because astronomers observe its gravitational pull on ordinary visible matter such as stars and galaxies.

Some theories suggest that, in addition to gravity, dark matter particles could interact with visible matter through a new force, which has so far escaped detection. Just as the electromagnetic force is carried by the photon, this dark force is thought to be transmitted by a particle called "dark" photon which is predicted to act as a mediator between visible and dark matter.

"To use a metaphor, an otherwise impossible dialogue between two people not speaking the same language (visible and dark matter) can be enabled by a mediator (the dark photon), who understands one language and speaks the other one," explains Sergei Gninenko, spokesperson for the NA64 collaboration.

CERN's NA64 experiment looks for signatures of this visible-dark interaction using a simple but powerful physics concept: the conservation of energy. A beam of electrons, whose initial energy is known very precisely, is aimed at a detector. Interactions between incoming electrons and atomic nuclei in the detector produce visible photons. The energy of these photons is measured and it should be equivalent to that of the electrons. However, if the dark photons exist, they will escape the detector and carry away a large fraction of the initial electron energy.

Therefore, the signature of the dark photon is an event registered in the detector with a large amount of "missing  If confirmed, the existence of the dark photon would represent a breakthrough in our understanding the longstanding dark matter mystery. [19]

## Shear brilliance: Computing tackles the mystery of the dark universe

Scientists from The University of Manchester working on a revolutionary telescope project have harnessed the power of distributed computing from the UK's GridPP collaboration to tackle one of the Universe's biggest mysteries – the nature of dark matter and dark energy.

Researchers at The University of Manchester have used resources provided by GridPP – who represent the UK's contribution to the computing grid used to find the Higgs boson at CERN – to run image processing and machine learning algorithms on thousands of images of galaxies from the international Dark Energy Survey.

The Manchester team are part of the collaborative project to build the Large Synoptic Survey Telescope (LSST), a new kind of telescope currently under construction in Chile and designed to conduct a 10-year survey of the dynamic Universe. LSST will be able to map the entire visible sky.

In preparation to the LSST starting its revolutionary scanning, a pilot research project has helped researchers detect and map out the cosmic shear seen across the night sky, one of the tell-tale signs of the dark matter and dark energy thought to make up some 95 per cent of what we see in the Universe. This in turn will help prepare for the analysis of the expected 200 petabytes of data the LSST will collect when it starts operating in 2023.

The pilot research team based at The Manchester of University was led by Dr Joe Zuntz, a cosmologist originally at Manchester's Jodrell Bank Observatory and now a researcher at the Royal Observatory in Edinburgh.

"Our overall aim is to tackle the mystery of the dark universe - and this pilot project has been hugely significant. When the LSST is fully operating researchers will face a galactic data deluge - and our work will prepare us for the analytical challenge ahead," said Sarah Bridle, Professor of Astrophysics.

Dr George Beckett, the LSST-UK Science Centre Project Manager based at The University of Edinburgh, added: "The pilot has been a great success. Having completed the work, Joe and his colleagues are able to carry out shear analysis on vast image sets much faster than was previously the case. Thanks are due to the members of the GridPP community for their assistance and support throughout."

The LSST will produce images of galaxies in a wide variety of frequency bands of the visible electromagnetic spectrum, with each image giving different information about the galaxy's nature and history. In times gone by, the measurements needed to determine properties like cosmic shear might have been done by hand, or at least with human-supervised computer processing.

With the billions of galaxies expected to be observed by LSST, such approaches are unfeasible. Specialised image processing and machine learning software (Zuntz 2013) has therefore been developed for use with galaxy images from telescopes like LSST and its predecessors. This can be used to produce cosmic shear maps like those shown in the figure below. The challenge then becomes one of processing and managing the data for hundreds of thousands of galaxies and extracting scientific results required by LSST researchers and the wider astrophysics community.

As each galaxy is essentially independent of other galaxies in the catalogue, the image processing workflow itself is highly parallelisable. This makes it an ideal problem to tackle with the kind of High-Throughput Computing (HTP) resources and infrastructure offered by GridPP. In many ways, the data from CERN's Large Hadron Collider particle collision events is like that produced by a digital camera (indeed, pixel-based detectors are used near the interaction points) – and GridPP regularly processes billions of such events as part of the Worldwide LHC Computing Grid (WLCG).

A pilot exercise, led by Dr Joe Zuntz while at The University of Manchester and supported by one of the longest serving and most experienced GridPP experts, Senior System Administrator Alessandra Forti, saw the porting of the image analysis workflow to GridPP's distributed computing infrastructure. Data from the Dark Energy Survey (DES) was used for the pilot.

After transferring this data from the US to GridPP Storage Elements, and enabling the LSST Virtual Organisation on a number of GridPP Tier-2 sites, the IM3SHAPE analysis software package (Zuntz, 2013) was tested on local, grid-friendly client machines to ensure smooth running on the grid. Analysis jobs were then submitted and managed using the Ganga software suite, which is able to coordinate the thousands of individual analyses associated with each batch of galaxies. Initial runs were submitted using Ganga to local grid sites, but the pilot progressed to submission to multiple sites via the GridPP DIRAC (Distributed Infrastructure with Remote Agent Control) service. The flexibility of Ganga allows both types of submission, which made the transition from local to distributed running significantly easier.

By the end of pilot, Dr Zuntz was able to run the image processing workflow on multiple GridPP sites, regularly submitting thousands of analysis jobs on DES images. [18]

## Supercomputer comes up with a profile of dark matter: Standard Model extension predicts properties of candidate particle

In the search for the mysterious dark matter, physicists have used elaborate computer calculations to come up with an outline of the particles of this unknown form of matter. To do this, the scientists extended the successful Standard Model of particle physics which allowed them, among other things, to predict the mass of so-called axions, promising candidates for dark matter. The German-

Hungarian team of researchers led by Professor Zoltán Fodor of the University of Wuppertal, Eötvös University in Budapest and Forschungszentrum Jülich carried out its calculations on Jülich's supercomputer JUQUEEN (BlueGene/Q) and presents its results in the journal Nature.

"Dark matter is an invisible form of matter which until now has only revealed itself through its gravitational effects. What it consists of remains a complete mystery," explains co-author Dr Andreas Ringwald, who is based at DESY and who proposed the current research. Evidence for the existence of this form of matter comes, among other things, from the astrophysical observation of galaxies, which rotate far too rapidly to be held together only by the gravitational pull of the visible matter.

High-precision measurements using the European satellite "Planck" show that almost 85 percent of the entire mass of the universe consists of dark matter. All the stars, planets, nebulae and other objects in space that are made of conventional matter account for no more than 15 percent of the mass of the universe.

"The adjective 'dark' does not simply mean that it does not emit visible light," says Ringwald. "It does not appear to give off any other wavelengths either - its interaction with photons must be very weak indeed." For decades, physicists have been searching for particles of this new type of matter. What is clear is that these particles must lie beyond the Standard Model of particle physics, and while that model is extremely successful, it currently only describes the conventional 15 percent of all matter in the cosmos. From theoretically possible extensions to the Standard Model physicists not only expect a deeper understanding of the universe, but also concrete clues in what energy range it is particularly worthwhile looking for dark-matter candidates.

The unknown form of matter can either consist of comparatively few, but very heavy particles, or of a large number of light ones. The direct searches for heavy dark-matter candidates using large detectors in underground laboratories and the indirect search for them using large particle accelerators are still going on, but have not turned up any dark matter particles so far. A range of physical considerations make extremely light particles, dubbed axions, very promising candidates. Using clever experimental setups, it might even be possible to detect direct evidence of them. "However, to find this kind of evidence it would be extremely helpful to know what kind of mass we are looking for," emphasises theoretical physicist Ringwald. "Otherwise the search could take decades, because one would have to scan far too large a range."

The existence of axions is predicted by an extension to quantum chromodynamics (QCD), the quantum theory that governs the strong interaction, responsible for the nuclear force. The strong interaction is one of the four fundamental forces of nature alongside gravitation, electromagnetism and the weak nuclear force, which is responsible for radioactivity. "Theoretical considerations indicate that there are so-called topological quantum fluctuations in quantum chromodynamics, which ought to result in an observable violation of time reversal symmetry," explains Ringwald. This means that certain processes should differ depending on whether they are running forwards or backwards. However, no experiment has so far managed to demonstrate this effect.

The extension to quantum chromodynamics (QCD) restores the invariance of time reversals, but at the same time it predicts the existence of a very weakly interacting particle, the axion, whose properties, in particular its mass, depend on the strength of the topological quantum fluctuations.

However, it takes modern supercomputers like Jülich's JUQUEEN to calculate the latter in the temperature range that is relevant in predicting the relative contribution of axions to the matter making up the universe. "On top of this, we had to develop new methods of analysis in order to achieve the required temperature range," notes Fodor who led the research.

The results show, among other things, that if axions do make up the bulk of dark matter, they should have a mass of 50 to 1500 micro-electronvolts, expressed in the customary units of particle physics, and thus be up to ten billion times lighter than electrons. This would require every cubic centimetre of the universe to contain on average ten million such ultra-lightweight particles. Dark matter is not spread out evenly in the universe, however, but forms clumps and branches of a weblike network. Because of this, our local region of the Milky Way should contain about one trillion axions per cubic centimetre.

Thanks to the Jülich supercomputer, the calculations now provide physicists with a concrete range in which their search for axions is likely to be most promising.

"The results we are presenting will probably lead to a race to discover these particles," says Fodor. Their discovery would not only solve the problem of dark matter in the universe, but at the same time answer the question why the strong interaction is so surprisingly symmetrical with respect to time reversal. The scientists expect that it will be possible within the next few years to either confirm or rule out the existence of axions experimentally.

The Institute for Nuclear Research of the Hungarian Academy of Sciences in Debrecen, the Lendület Lattice Gauge Theory Research Group at the Eötvös University, the University of Zaragoza in Spain, and the Max Planck Institute for Physics in Munich were also involved in the research. [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.”

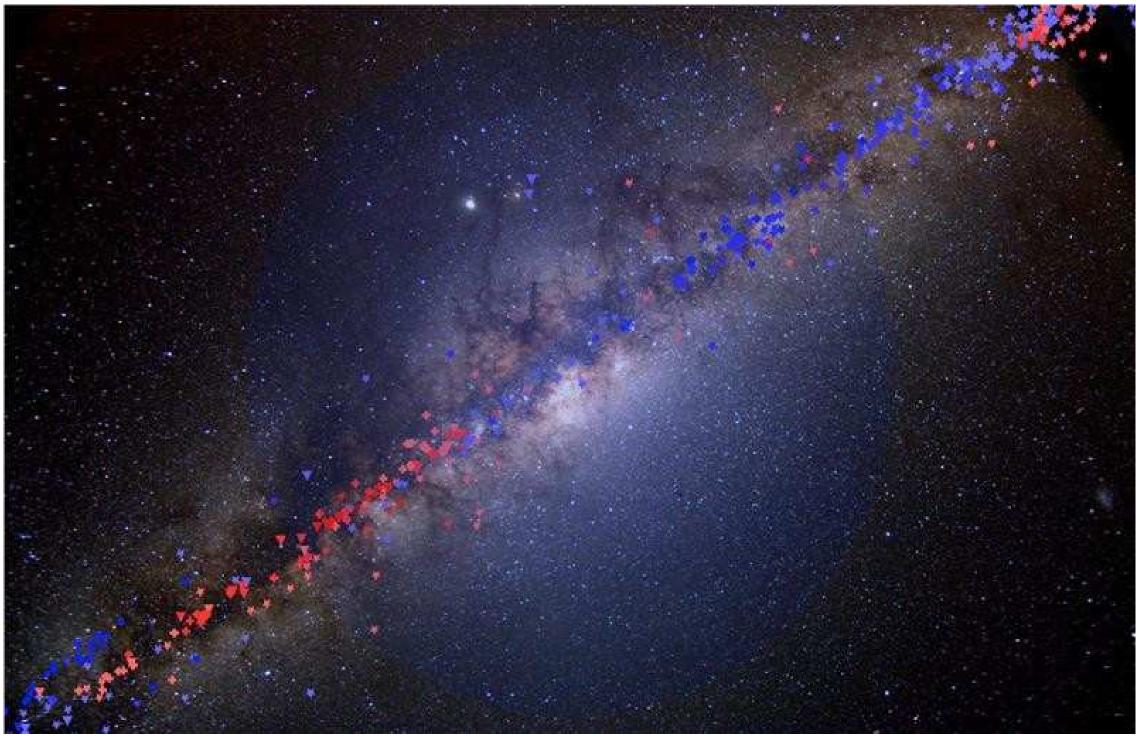
But other experiments have not used the same technology as DAMA, says theoretical astrophysicist Katherine Freese of the University of Michigan in Ann Arbor.

“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!?

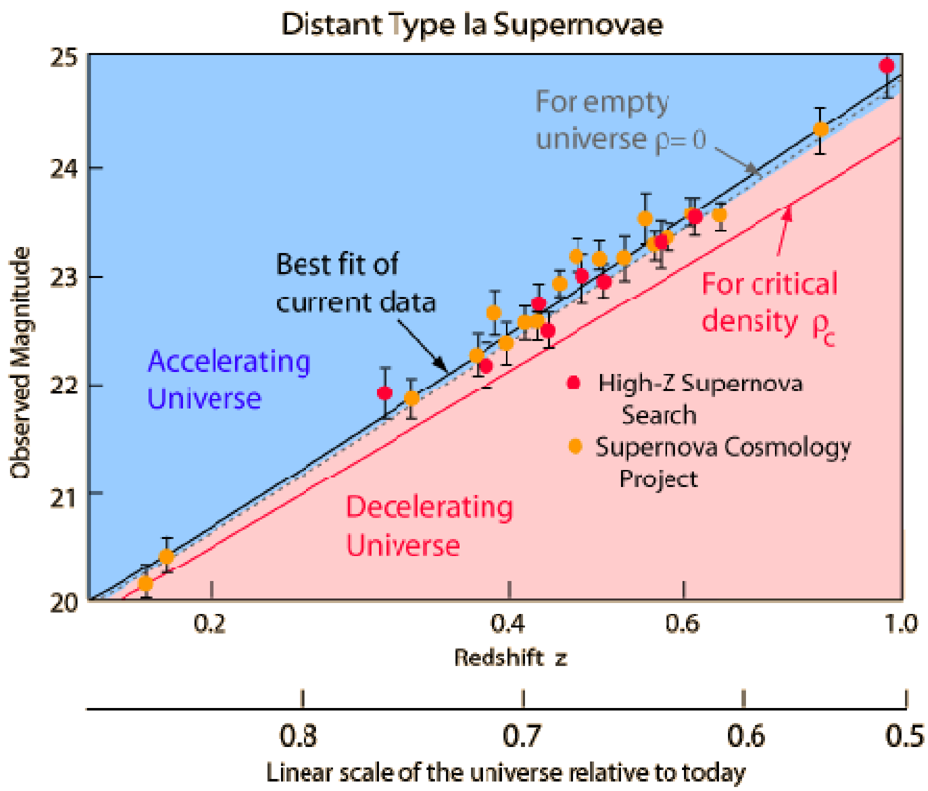
The gravitational force attracting the matter, causing concentration of the matter in a small space and leaving much space with low matter concentration: dark matter and energy.

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, $\rho_{vac}$ (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

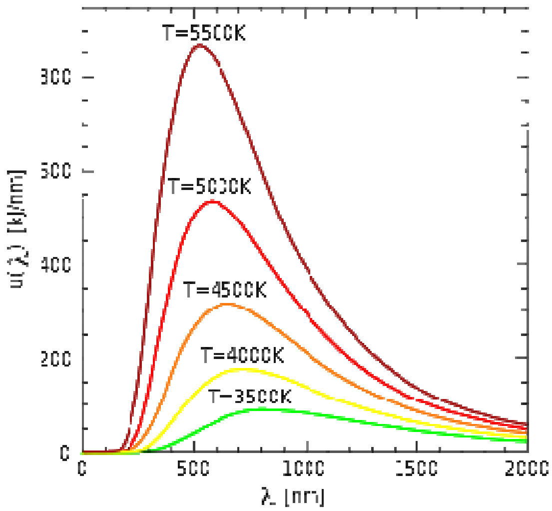
Dark matter is a type of matter hypothesized in astronomy and cosmology to account for a large part of the mass that appears to be missing from the universe. Dark matter cannot be seen directly with telescopes; evidently it neither emits nor absorbs light or other electromagnetic radiation at any significant 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

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### Relativistic change of mass

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### The frequency dependence of mass

Since $E = h\nu$ and $E = mc^2$, $m = h\nu / c^2$ that is the $m$ depends only on the $\nu$ 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.

### 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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