

# CERN Sensor of Gravitational Wave

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

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

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Author: George Rajna

## The Big Bang

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

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

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.

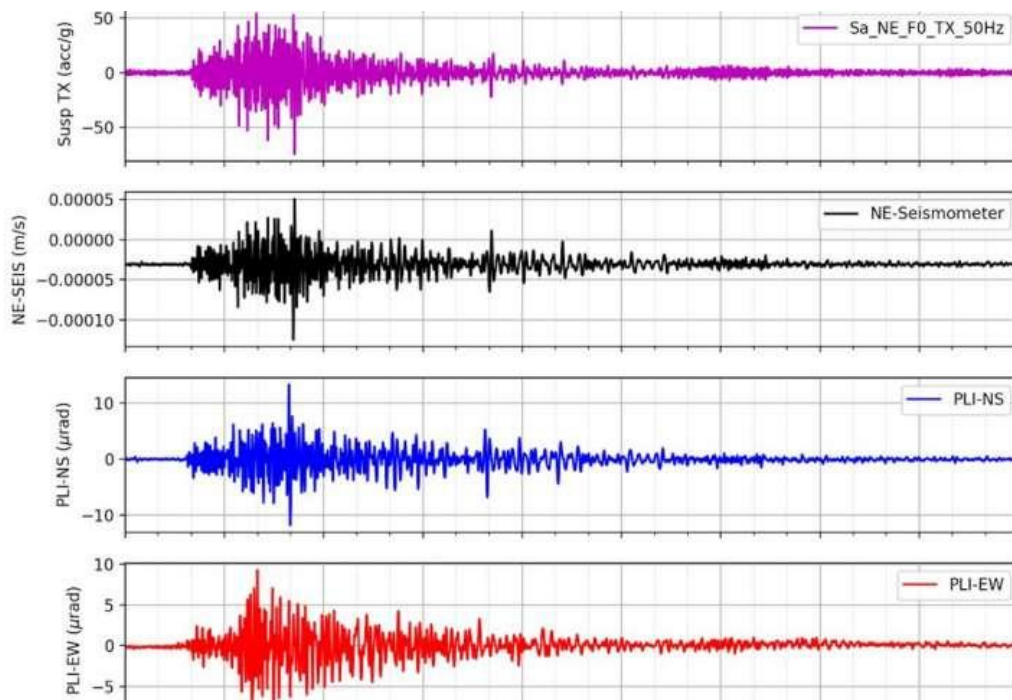
## Sensor used at CERN could help gravitational wave hunters

It started with a relatively simple goal: create a prototype for a new kind of device to monitor the motion of underground structures at CERN. But the project—the result of a collaboration between CERN and the Joint Institute for Nuclear Research (JINR) in Dubna, Russia—quickly evolved. The prototype turned into several full-blown devices that can potentially serve as early warning systems for earthquakes and can be used to monitor other seismic vibrations. What's more, the devices,

called precision laser inclinometers, can be used at CERN and beyond. The researchers behind the project are now testing one device at the Advanced Virgo detector, which recently detected gravitational waves—tiny ripples in the fabric of space-time that were predicted by Einstein a century ago. If all goes to plan, this device could help gravitational-wave hunters minimize the noise that seismic events have on the waves' signal.

Unlike traditional seismometers, which detect ground motions through their effect on weights hanging from springs, the precision laser inclinometer (PLI) measures their effect on the surface of a liquid. The measurement is done by pointing laser light at a liquid and seeing how it is reflected. Compared to weight–spring seismometers, the PLI can detect angular motion in addition to translational motion (up-and-down and side-to-side), and it can pick up low-frequency motion with a very high precision.

"The PLI is extremely sensitive, it can even detect the waves on Lake Geneva on windy days," says principal investigator Beniamino Di Girolamo from CERN. "It can pick up seismic motion that has a frequency between 1 mHz and 12.4 Hz with a sensitivity of  $2.4 \times 10^{-5} \mu\text{rad}/\text{Hz}^{1/2}$ ," explains co-principal investigator Julian Budagov from JINR. "This is equivalent to measuring a vertical displacement of 24 picometers (24 trillionth of a meter) over a distance of 1 meter," adds co-principal investigator Mikhail Lyablin, also from JINR.



The PLI (bottom two plots) picked up the same signals as devices already installed at Virgo (top two plots) for an earthquake in Northern Italy on 17 August. Credit: Beniamino Di Girolamo/CERN

The team assembled and tested the PLI prototype at JINR and at CERN's TT1 tunnel. It performed so well that it showed potential to be a helpful early warning seismic system for the High-Luminosity Large Hadron Collider (HL-LHC) and other machines and experiments. The Large Hadron Collider and its proton beams are extremely robust to seismic activity, but the HL-LHC will use narrower beams to increase the number of proton–proton collisions and as a result the potential for particle-

physics discoveries. This means beams are more likely to go off center in the event of a high-magnitude earthquake with an epicenter relatively close to CERN. PLIs located at several points along the machine could serve as early warning systems for such events.

Given the PLI's potential, the HL-LHC project has supported the team to construct several new PLIs. One PLI is already installed at the Garni Seismic Observatory in Armenia and another has been deployed with the support of CERN's Knowledge Transfer group and Italy's INFN institute to the European Gravitational Observatory, Italy, where Advanced Virgo is located. The Virgo PLI is the result of a collaboration that started after the APPEC conference in November 2018, triggered by the JINR Director-General and encouraged by CERN management. The collaboration went so smoothly that, less than a year after, the Virgo PLI was tested.

The results from the first tests are encouraging. With just 15 minutes of data taken on 6 August, the PLI picked up the same signals as devices already installed at Virgo, and from that day onwards it started running continuously and detected several small-magnitude earthquakes. The Virgo and PLI teams are now setting up the flow of data from the PLI to the Virgo data system. This will make it easier to compare data from different seismic devices and to assess the PLI's potential impact on Virgo's operation and detection of [gravitational waves](#). "Virgo and the two LIGO detectors in the US have recently began another search for gravitational waves, one that will reach deeper into the universe than previous searches," says former Virgo spokesperson Fulvio Ricci from La Sapienza University, Rome. "We're confident that the PLI can play a part in this important search," he added. [21]

## **Miniature gravitational-wave detector to be built at Northwestern**

A team of physicists and astronomers from Northwestern University is poised to lead gravitational-wave astronomy into its next evolution. The W. M. Keck Foundation has awarded \$1 million, which will be used to develop a prototype for a new kind of gravitational-wave detector that is small enough to fit on a tabletop and powerful enough to detect cosmic events that existing astronomical equipment cannot.

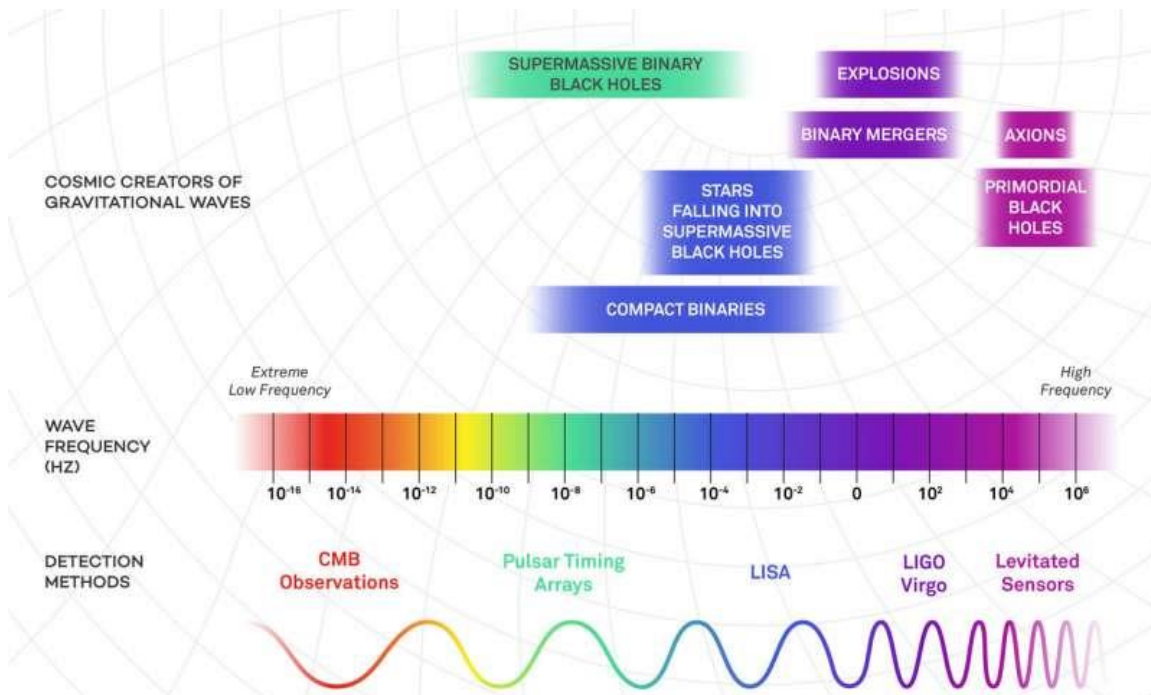
"This is the start of the next phase of gravitational-wave and multi-messenger astronomy," said Andrew Geraci, principal investigator on the project. "This tabletop sensor will be able to observe events we've never seen before, expanding our understanding of space and the universe."

Geraci is an associate professor of physics and astronomy in Northwestern's Weinberg College of Arts and Sciences and a faculty member of the Center for Fundamental Physics (CFP) and the Center for Interdisciplinary Exploration and Research for Astrophysics (CIERA) at Northwestern.

The Levitated Sensor Detector will extend the spectrum of detectable gravitational waves to higher frequencies, possibly opening a window to the types of events that are related to the mysterious dark matter in the universe. It will complement research being conducted at the Laser Interferometer Gravitational-Wave Observatory (LIGO) and Virgo observatories, which occupy

several acres of land in the United States and Italy, by observing smaller cosmic events that produce waves at a [frequency](#) LIGO and Virgo cannot detect.

"If you think of gravitational waves like sound waves, the frequency we are trying to capture with levitated sensors is sort of like a dog whistle," said Vicky Kalogera, project co-investigator and CIERA director.



Infographic shows the full landscape of gravitational wave-causing events and the sensors capable of detecting them. Definitions of cosmic events are removed from this version. Credit: Northwestern University

"Dogs are capable of hearing sound frequencies that the human ear cannot perceive. Similarly, levitated sensors will pick up frequencies that LIGO and Virgo cannot detect," said Kalogera, who also is the Daniel I. Linzer Distinguished University Professor of Physics and Astronomy and one of the foremost astrophysicists in the LIGO Scientific Collaboration (LSC).

Northwestern scientists will spend two years building and testing the levitated sensor prototype, which will consist of two arms in an L-formation, each measuring about one meter in length. The levitated sensor will then operate for a one-year observing run, the results of which will be shared with the international gravitational-wave and astronomy communities.

Levitated [sensors](#) will be capable of detecting cosmic events that produce gravitational waves with a frequency of greater than 10 kHz. These events are thought to be the result of small cosmic events involving [black holes](#) similar in mass to Earth's sun, and primordial black holes produced in the earliest days of the universe. Astrophysicists theorize but have so far been unable to prove that these events are responsible for the creation of dark matter. Other dark matter candidates such as axions, hypothetical particles that are predicted to be a component of cold dark matter, also can be searched for using the device.

Development of this tabletop detector coincides with the development of a third type of detector on the opposite end of the frequency spectrum. The European Space Agency plans to launch LISA, a space-based gravitational-wave detector that spans tens of millions of miles, in the early 2030s.

"Just like electromagnetic astronomy has telescopes and gamma-ray detectors and more, the [gravitational-wave](#) community is now developing the tools needed to detect events on all parts of the spectrum," project co-investigator Shane Larson said. "LISA will detect the big events; LIGO and Virgo pick up the medium events; and LSD will detect the smallest [cosmic events](#)." [20]

## **LIGO upgrade to allow 'almost daily' detection of gravitational waves**

The UK and US have announced a \$35m upgrade to the Advanced Laser Interferometer Gravitational-wave Observatory ([aLIGO](#)). The improvement will see the twin observatories — located near Hanford, Washington and Livingston, Louisiana in the US — double their sensitivity to gravitational waves. Work on the upgrade will start in 2023 and be complete two years later.

Each LIGO facility works by sending twin laser beams down two 4 km-long tubes — arranged as an L-shape — that are kept under a near-perfect vacuum. The beams are reflected back down the tubes by mirrors precisely positioned at the ends of each arm. As a gravitational wave passes through the observatory, it causes extremely tiny distortions in the distance travelled by each laser beam.

LIGO first turned on 2002 and was upgraded between 2010 and 2015 to improve the facilities' ability to spot gravitational waves by a factor of 10. Thanks to this \$221m upgrade — known as Advanced LIGO, or aLIGO — researchers can detect gravitational waves that originate anywhere within a sphere of about 420 million light-years in radius, centred on the Earth.

[That breakthrough was announced in February 2016](#) when researchers working on aLIGO directly detected gravitational waves for the first time in an event in September 2015 — when aLIGO was being calibrated. The waves were produced from the collision of two black holes of 36 and 29 solar masses, respectively, which merged to form a spinning, 62-solar-mass black hole, some 1.3 billion light-years (410 mpc) away in an event dubbed GW150914. The finding ended the decades-long hunt for these ripples in space-time and marked the beginning of a new era of gravitational-wave astronomy that has since resulted in around 10 gravitational-wave events being detected including from the merger of two neutron stars.

### Reducing noise

While aLIGO is set to begin another operating run in the next couple of months, plans are now afoot to boost its sensitivity even further. The US National Science Foundation ([NSF](#)) announced today that it will provide \$20.4m for a further upgrade to the facility, dubbed aLIGO+. The [UK Research and Innovation](#), meanwhile, will provide a further \$14.1m with additional support from the [Australian Research Council](#).

The upgrades will include applying new coatings to the mirrors to reduce thermal noise as well as improvements to the laser system. aLIGO+'s capabilities are expected to probe the origins and evolution of stellar-mass black holes as well as allow precision tests of extreme gravity and enable detailed study of the equation of state of neutron stars.



### Catching gravity, rolling by

“This award ensures that LIGO will continue to lead in gravitational wave science for the next decade,” says NSF Director [France Córdova](#). “These detections may reveal secrets from inside supernovae and teach us about extreme physics from the first seconds after the universe’s birth.”

According to [David Reitze](#), executive director of the LIGO Laboratory, the upgrades will see the observatory being able to detect binary black hole collisions on “an almost daily basis”. The improvement will also be made “as standard” to the planned LIGO facility in India, which, if built, is expected to come online in 2025. [19]



## Boosting gravitational wave detectors with quantum tricks

A group of scientists from the Niels Bohr Institute (NBI) at the University of Copenhagen will soon start developing a new line of technical equipment in order to dramatically improve gravitational wave detectors.

Gravitational wave detectors are extremely sensitive and can e.g. register colliding neutron stars in space. Yet even higher sensitivity is sought for in order to expand our knowledge about the Universe, and the NBI-scientists are convinced that their equipment can improve the detectors, says Professor Eugene Polzik: "And we should be able to show proof of concept within approximately three years."

If the NBI-scientists are able to improve the gravitational wave detectors as much as they "realistically expect can be done," the detectors will be able to monitor and carry out measurements in an eight times bigger volume of space than what is currently possible, explains Eugene Polzik: "This will represent a truly significant extension."

Polzik is head of Quantum Optics (Quantop) at NBI and he will spearhead the development of the tailor made equipment for gravitational wave detectors. The research – which is supported by the EU, the Eureka Network Projects and the US-based John Templeton Foundation with grants totaling DKK 10 million – will be carried out in Eugene Polzik's lab at NBI.

## A collision well noticed

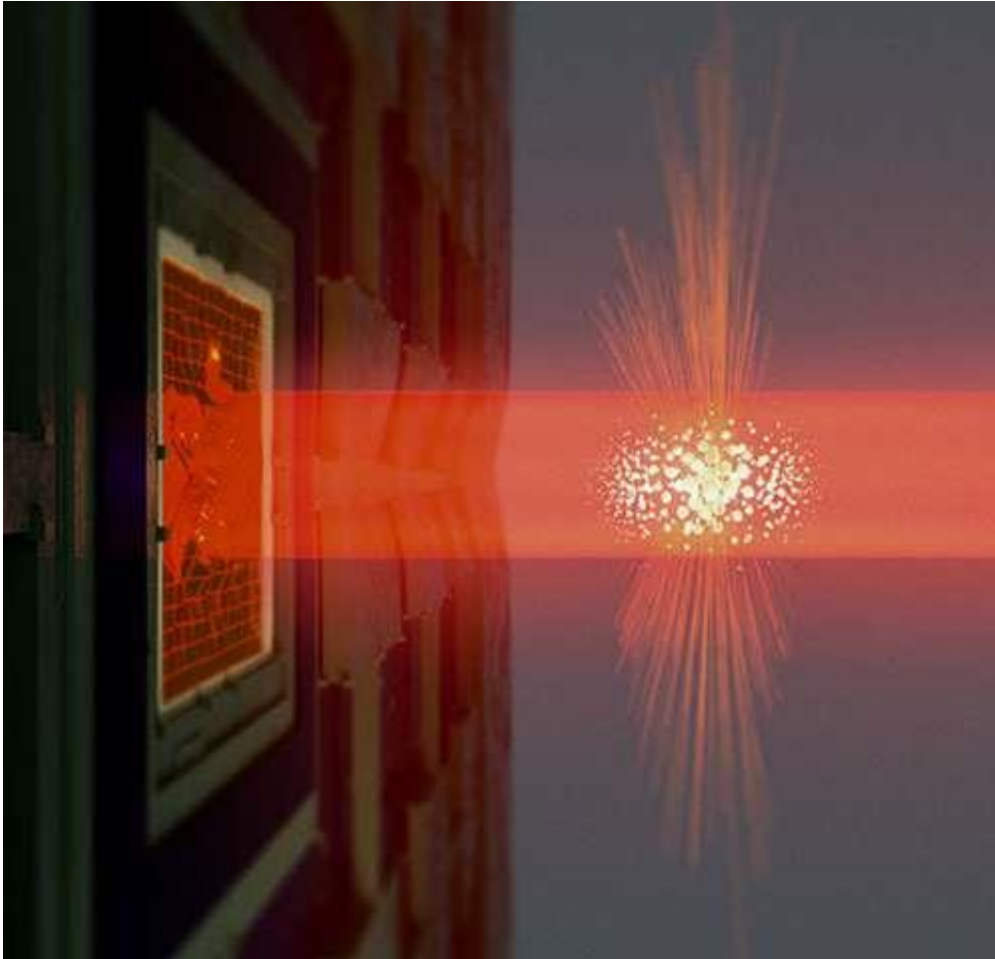
News media all over the world shifted into overdrive in October of 2017 when it was confirmed that a large international team of scientists had indeed measured the collision of two neutron stars; an event which took place 140 million light years from Earth and resulted in the formation of a kilonova.

The international team of scientists – which also included experts from NBI – was able to confirm the collision by measuring gravitational waves from space – waves in the fabric of spacetime itself, moving at the speed of light. The waves were registered by three gravitational wave detectors: the two US-based LIGO-detectors and the European Virgo-detector in Italy.

"These gravitational wave detectors represent by far the most sensitive measuring equipment man has yet manufactured – still the detectors are not as accurate as they could possibly be. And this is what we intend to improve," says Professor Eugene Polzik.

How this can be done is outlined in an article which Eugene Polzik and a colleague, Farid Khalili from LIGO collaboration and Moscow State University, have recently published in the scientific journal *Physical Review Letters*. And this is not merely a theoretical proposal, says Eugene Polzik:

"We are convinced this will work as intended. Our calculations show that we ought to be able to improve the precision of measurements carried out by the gravitational wave detectors by a factor of two. And if we succeed, this will result in an increase by a factor of eight of the volume in space which gravitational wave detectors are able to examine at present."



If laser light used to measure motion of a vibrating membrane (left) is first transmitted through an atom cloud (center) the measurement sensitivity can be better than standard quantum limits envisioned by Bohr and Heisenberg. Credit: Bastian Leonhardt Strube and Mads Vadsholt

### **A small glass cell**

In July of last year Eugene Polzik and his team at Quantop published a highly noticed article in *Nature* – and this work is actually the very foundation of their upcoming attempt to improve the gravitational wave detectors.

The article in *Nature* centered on 'fooling' Heisenberg's Uncertainty Principle, which basically says that you cannot simultaneously know the exact position and the exact speed of an object.

This has to do with the fact that observations conducted by shining light on an object inevitably will lead to the object being 'kicked' in random directions by photons, particles of light. This phenomenon is known as Quantum Back Action (QBA) and these random movements put a limit to the accuracy with which measurements can be carried out at the quantum level.

The article in *Nature* in the summer of 2017 made headlines because Eugene Polzik and his team were able to show that it is – to a large extent – actually possible to neutralize QBA.

And QBA is the very reason why gravitational wave detectors – that also operate with light, namely laser light—are not as accurate as they could possibly be," as professor Polzik says.

Put simply, it is possible to neutralize QBA if the light used to observe an object is initially sent through a 'filter.' This was what the article in Nature described – and the 'filter' which the NBI-scientists at Quantop had developed and described consisted of a cloud of 100 million caesium atoms locked-up in a hermetically closed glass cell just one centimeter long, 1/3 of a millimeter high and 1/3 of a millimeter wide.

The principle behind this 'filter' is exactly what Polzik and his team are aiming to incorporate in gravitational wave detectors.

In theory one can optimize measurements of gravitational waves by switching to stronger laser light than the detectors in both Europe and USA are operating with. However, according to quantum mechanics, that is not an option, says Eugene Polzik:

"Switching to stronger laser light will just make a set of mirrors in the detectors shake more because Quantum Back Action will be caused by more photons. These mirrors are absolutely crucial, and if they start shaking, it will in fact increase inaccuracy."

Instead, the NBI-scientists have come up with a plan based on the atomic 'filter' which they demonstrated in the Nature article: They will send the laser light by which the gravitational wave detectors operate through a tailor made version of the cell with the locked-up atoms, says Eugene Polzik: "And we hope that it will do the job." [18]

## **Gravitational wave detectors could shed light on dark matter**

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

## Synopsis: Dark Photon Conjecture Fizzles

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

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

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

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

## Exchanges of identity in deep space

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

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

A possible explanation for this surprising anomaly is that light photons are transformed into hypothetical weakly interacting particles, “axions,” which, in turn, would change into photons, all due to the interaction with magnetic fields. A part of the photons would escape interaction with the intergalactic background light that would make them disappear. The importance of this process is emphasised by a study published in Physical Review Letters, which recreated an extremely

refined model of the cosmic web, a network of filaments composed of gas and dark matter present throughout the universe, and of its magnetic fields. These effects are now awaiting comparison with those obtained experimentally through Cherenkov Telescope Array new generation telescopes.

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

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

## **Astronomers may have detected the first direct evidence of dark matter**

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

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

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

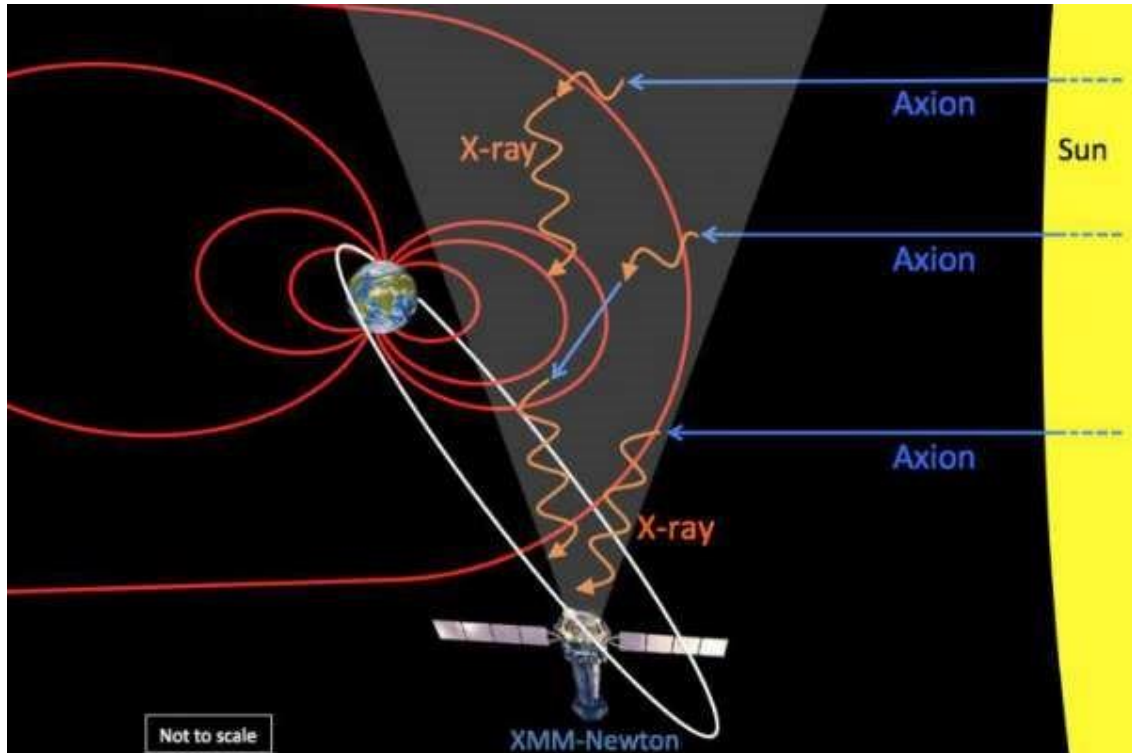
The researchers first detected the signal while searching through 15 years of measurements taking by the European Space Agency's orbiting XMM-Newton space observatory.

Unexpectedly, they noticed that the intensity of X-rays recorded by the spacecraft rose by about 10% whenever XMM-Newton was at the boundary of Earth's magnetic field facing the Sun - even once they removed all the bright X-ray sources from the sky. Usually, that X-ray background is stable. "The X-ray background - the sky, after the bright X-ray sources are removed - appears to be unchanged whenever you look at it," said Andy Read, from the University of Leicester, one of the lead authors on the paper, in a press release. "However, we have discovered a seasonal signal in

this X-ray background, which has no conventional explanation, but is consistent with the discovery of axions."

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

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



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

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

## Hidden photons

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

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

### **Ideal mirror at hand**

Fortunately for the team, an ideal mirror is at hand: a 13 m<sup>2</sup> aluminium mirror used in tests during the construction of the Pierre Auger Observatory and located at the Karlsruhe Institute of Technology. Döbrich and co-workers have got together with several researchers from Karlsruhe, and the collaboration is now readying the mirror by adjusting the position of each of its 36 segments to minimize the spot size of the focused waves. They are also measuring background radiation within the shielded room that will house the experiment. As for receivers, the most likely initial option is a set of low-noise photomultiplier tubes for measurements of visible light, which corresponds to hidden-photon masses of about 1 eV/c<sup>2</sup>. Another obvious choice is a receiver for gigahertz radiation, which corresponds to masses less than 0.001 eV/c<sup>2</sup>; however, this latter set-up would require more shielding.

### **Dark matter composition research - WIMP**

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

### **Weakly interacting massive particles**

In particle physics and astrophysics, weakly interacting massive particles, or WIMPs, are among the leading hypothetical particle physics candidates for dark matter. The term “WIMP” is given to a



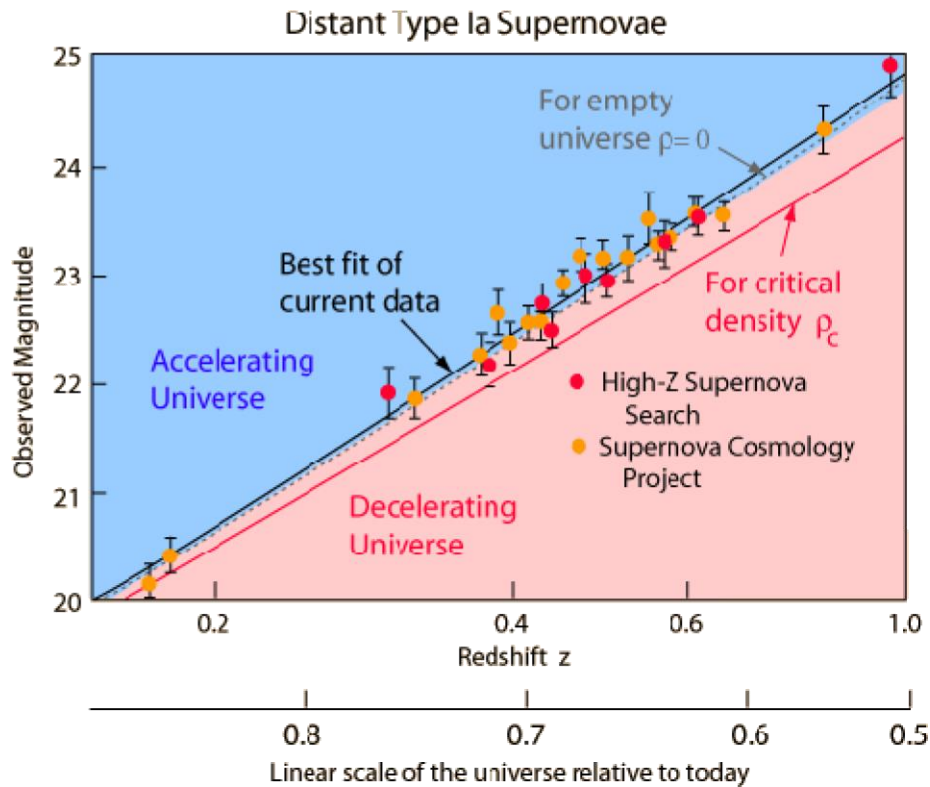
dark matter particle that was produced by falling out of thermal equilibrium with the hot dense plasma of the early universe, although it is often used to refer to any dark matter candidate that interacts with standard particles via a force similar in strength to the weak nuclear force. Its name comes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

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

## Evidence for an accelerating universe

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

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



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

### Equation

The cosmological constant  $\Lambda$  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  $\Lambda$  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  $8\pi$ :  $\Lambda = 8\pi\rho_{vac}$ , where unit conventions of general relativity are used (otherwise factors of  $G$  and  $c$  would also appear). It is common to quote values of energy density directly, though still using the name "cosmological constant".

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

## Explanatory models

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

## Dark Matter and Energy

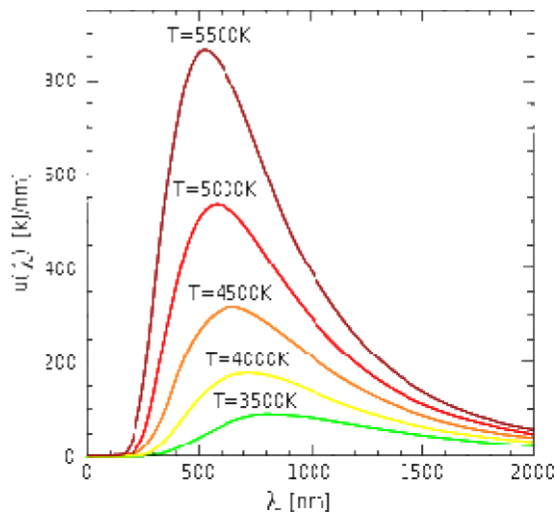
Dark matter is a type of matter hypothesized in astronomy and cosmology to account for a large part of the mass that appears to be missing from the universe. Dark matter cannot be seen directly with telescopes; evidently it neither emits nor absorbs light or other electromagnetic radiation at any significant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

## Cosmic microwave background

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

## Thermal radiation

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



## Electromagnetic Field and Quantum Theory

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

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

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

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

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

## Lorentz transformation of the Special Relativity

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

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

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

The increasing mass of the electric charges the result of the increasing inductive electric force acting against the accelerating force. The decreasing mass of the decreasing acceleration is the result of the inductive electric force acting against the decreasing force. This is the relativistic mass change explanation, especially importantly explaining the mass reduction in case of velocity decrease.

## The Classical Relativistic effect

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

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

## Electromagnetic inertia and Gravitational attraction

Since the magnetic induction creates a negative electric field as a result of the changing acceleration, it works as an electromagnetic inertia, causing an electromagnetic mass.

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

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

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

The Planck distribution law explains the different frequencies of the proton and electron, giving equal intensity to different lambda wavelengths! Also since the particles are diffraction patterns they have some closeness to each other – can be seen as a gravitational force.

## Electromagnetic inertia and mass

### Electromagnetic Induction

Since the magnetic induction creates a negative electric field as a result of the changing acceleration, it works as an electromagnetic inertia, causing an electromagnetic mass. [1]

### Relativistic change of mass

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### The frequency dependence of mass

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### Electron – Proton mass rate

The Planck distribution law explains the different frequencies of the proton and electron, giving equal intensity to different lambda wavelengths! Also since the particles are diffraction patterns they have some closeness to each other – can be seen as a gravitational force. [1]

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

## Gravity from the point of view of quantum physics

### The Gravitational force

The gravitational attractive force is basically a magnetic force.

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

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

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

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

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

### The Graviton

In physics, the graviton is a hypothetical elementary particle that mediates the force of gravitation in the framework of quantum field theory. If it exists, the graviton is expected to be massless (because the gravitational force appears to have unlimited range) and must be a spin-2 boson. The spin follows from the fact that the source of gravitation is the stress-energy tensor, a second-rank tensor (compared to electromagnetism's spin-1 photon, the source of which is the four-current, a first-rank tensor). Additionally, it can be shown that any massless spin-2 field would give rise to a force indistinguishable from gravitation, because a massless spin-2 field must couple to (interact with) the stress-energy tensor in the same way that the gravitational field does. This result suggests that, if a massless spin-2 particle is discovered, it must be the graviton, so that the only experimental verification needed for the graviton may simply be the discovery of a massless spin-2 particle. [2]

### Conclusions

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

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

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

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

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

There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a high probability event. The asymmetric sides are creating different frequencies of electromagnetic radiations being in the same intensity level and compensating each other. One of these compensating ratios is the electron – proton mass ratio. The lower energy side has no compensating intensity level, it is the dark energy and the corresponding matter is the dark matter. The electric currents causing self maintaining electric potential is the source of the special and general relativistic effects. The Higgs Field is the result of the electromagnetic induction. The Graviton is two photons together. [3]

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