

# Dwarf Galaxies with Dark Matter

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*One of the biggest mysteries of dwarf galaxies has to do with dark matter, which is why scientists are so fascinated by them. [17]*

*Using the world's most powerful telescopes, an international team of astronomers has found a massive galaxy that consists almost entirely of dark matter. [16]*

*Astrophysicists from the Johns Hopkins University have proposed a clever new way of shedding light on the mystery of dark matter, believed to make up most of the universe. [15]*

*"These studies are providing increasingly sensitive results, slowly shrinking the box of parameters where dark matter particles can hide," said Alexander Kashlinsky, an astrophysicist at NASA's Goddard Space Flight Center. "The failure to find them has led to renewed interest in studying how well primordial black holes -- black holes formed in the universe's first fraction of a second -- could work as dark matter." [14]*

*"There seems to be a mysterious link between the amount of dark matter a galaxy holds and the size of its central black hole, even though the two operate on vastly different scales," said Akos Bogdan of the Harvard-Smithsonian Center for Astrophysics (CfA). [13]*

*If dark matter comes in both matter and antimatter varieties, it might accumulate inside dense stars to create black holes. [12]*

*For a long time, there were two main theories related to how our universe would end. These were the Big Freeze and the Big Crunch. In short, the Big Crunch claimed that the universe would eventually stop expanding and collapse in on itself. This collapse would result in...well...a big crunch (for lack of a better term). Think "the Big Bang", except just the opposite. That's essentially what the Big Crunch is. On the other hand, the Big Freeze claimed that the universe would continue expanding forever, until the cosmos becomes a frozen wasteland. This theory asserts that stars will get farther and farther apart, burn out, and (since there are no more stars being born) the universe will grow entirely cold and eternally black. [11]*

*Newly published research reveals that dark matter is being swallowed up by dark energy, offering novel insight into the nature of dark matter and dark energy and what the future of our Universe might be. [10]*

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

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

## **Contents**

Reconciling dwarf galaxies with dark matter .....	3
Scientists discover a 'dark' Milky Way: Massive galaxy consists almost entirely of dark matter .....	4
Can one cosmic enigma help solve another? Astrophysicists argue fast radio bursts could provide clues to dark matter .....	5
Dark Matter is Made of Black Holes Formed During First Second of Our Universe's Existence.....	7
"Unsolved Link" --Between Dark Matter and Supermassive Black Holes .....	9
Dark Matter Black Holes Could Be Destroying Stars at the Milky Way's Center .....	10
Everything You Need to Know About Dark Energy .....	12
How We Discovered That The Universe Is Expanding:.....	12
How Do We Know That Dark Energy Is Real? .....	13
How Does Dark Energy Work? .....	14
The Problem With Dark Energy:.....	14
The Significance: .....	15
The Big Bang .....	15
Study Reveals Indications That Dark Matter is Being Erased by Dark Energy .....	15
Evidence for an accelerating universe .....	16
Equation .....	17
Explanatory models.....	18
Dark Matter and Energy .....	18
Cosmic microwave background .....	18
Thermal radiation .....	18

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

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## Reconciling dwarf galaxies with dark matter

Dwarf galaxies are enigmas wrapped in riddles. Although they are the smallest galaxies, they represent some of the biggest mysteries about our universe. While many dwarf galaxies surround our own Milky Way, there seem to be far too few of them compared with standard cosmological models, which raises a lot of questions about the nature of dark matter and its role in galaxy formation.

New theoretical modeling work from Andrew Wetzel, who holds a joint fellowship between Carnegie and Caltech, offers the most accurate predictions to date about the dwarf galaxies in the Milky Way's neighborhood. Wetzel achieved this by running the highest-resolution and most-detailed simulation ever of a galaxy like our Milky Way. His findings, published by The Astrophysical Journal Letters, help to resolve longstanding debates about how these dwarf galaxies formed.

One of the biggest mysteries of dwarf galaxies has to do with dark matter, which is why scientists are so fascinated by them.

"Dwarf galaxies are at the nexus of dark matter science," Wetzel said.

Dark matter makes up a quarter of our universe. It exerts a gravitational pull, but doesn't seem to interact with regular matter—like atoms, stars, and us—in any other way. We know it exists because of the gravitational effect it has on stars and gas and dust. This effect is why it is key to understanding galaxy formation. Without dark matter, galaxies could not have formed in our universe as they did. There just isn't enough gravity to hold them together without it.

The role of dark matter in the formation of dwarf galaxies has remained a mystery. The standard cosmological model has told us that, because of dark matter, there should be many more dwarf galaxies out there, surrounding our own Milky Way, than we have found. Astronomers have developed a number of theories for why we haven't found more, but none of them could account for both the paucity of dwarf galaxies and their properties, including their mass, size, and density.

As observation techniques have improved, more dwarf galaxies have been spotted orbiting the Milky Way. But still not enough to align with predictions based on standard cosmological models.

So scientists have been honing their simulation techniques in order to bring theoretical modeling predictions and observations into better agreement. In particular, Wetzel and his collaborators worked on carefully modeling the complex physics of stellar evolution, including how supernovae—the fantastic explosions that punctuate the death of massive stars—affect their host galaxy.

With these advances, Wetzel ran the most-detailed simulation of a galaxy like our Milky Way. Excitingly, his model resulted in a population of dwarf galaxies that is similar to what astronomers observe around us.

As Wetzel explained: "By improving how we modeled the physics of stars, this new simulation offered a clear theoretical demonstration that we can, indeed, understand the dwarf galaxies we've observed around the Milky Way. Our results thus reconcile our understanding of dark matter's role in the universe with observations of dwarf galaxies in the Milky Way's neighborhood."

Despite having run the highest-resolution simulation to date, Wetzel continues to push forward, and he is in the process of running an even higher-resolution, more-sophisticated simulation that will allow him to model the very faintest dwarf galaxies around the Milky Way.

"This mass range gets interesting, because these 'ultra-faint' dwarf galaxies are so faint that we do not yet have a complete observational census of how many exist around the Milky Way. With this next simulation, we can start to predict how many there should be for observers to find," he added.

[17]

## **Scientists discover a 'dark' Milky Way: Massive galaxy consists almost entirely of dark matter**

Using the world's most powerful telescopes, an international team of astronomers has found a massive galaxy that consists almost entirely of dark matter.

The galaxy, Dragonfly 44, is located in the nearby Coma constellation and had been overlooked until last year because of its unusual composition: It is a diffuse "blob" about the size of the Milky Way, but with far fewer stars.

"Very soon after its discovery, we realized this galaxy had to be more than meets the eye. It has so few stars that it would quickly be ripped apart unless something was holding it together," said Yale University astronomer Pieter van Dokkum, lead author of a paper in the *Astrophysical Journal Letters*.

Van Dokkum's team was able to get a good look at Dragonfly 44 thanks to the W.M. Keck Observatory and the Gemini North telescope, both in Hawaii.

Astronomers used observations from Keck, taken over six nights, to measure the velocities of stars in the galaxy. They used the 8-meter Gemini North telescope to reveal a halo of spherical clusters of stars around the galaxy's core, similar to the halo that surrounds our Milky Way galaxy.

Star velocities are an indication of the galaxy's mass, the researchers noted. The faster the stars move, the more mass its galaxy will have.

"Amazingly, the stars move at velocities that are far greater than expected for such a dim galaxy. It means that Dragonfly 44 has a huge amount of unseen mass," said co-author Roberto Abraham of the University of Toronto.

Scientists initially spotted Dragonfly 44 with the Dragonfly Telephoto Array, a telescope invented and built by van Dokkum and Abraham.

Dragonfly 44's mass is estimated to be 1 trillion times the mass of the Sun, or 2 tredecillion kilograms (a 2 followed by 42 zeros), which is similar to the mass of the Milky Way. However, only one-hundredth of 1% of that is in the form of stars and "normal" matter. The other 99.99% is in the form of dark matter—a hypothesized material that remains unseen but may make up more than 90% of the universe.

The researchers note that finding a galaxy composed mainly of dark matter is not new; ultra-faint dwarf galaxies have similar compositions. But those galaxies were roughly 10,000 times less massive than Dragonfly 44.

"We have no idea how galaxies like Dragonfly 44 could have formed," said Abraham. "The Gemini data show that a relatively large fraction of the stars is in the form of very compact clusters, and that is probably an important clue. But at the moment we're just guessing."

Van Dokkum, the Sol Goldman Family Professor of Astronomy and Physics at Yale, added:

"Ultimately what we really want to learn is what dark matter is. The race is on to find massive dark galaxies that are even closer to us than Dragonfly 44, so we can look for feeble signals that may reveal a dark matter particle."

Additional co-authors are Shany Danieli, Allison Merritt, and Lamiya Mowla of Yale, Jean Brodie of the University of California Observatories, Charlie Conroy of Harvard, Aaron Romanowsky of San Jose State University, and Jielai Zhang of the University of Toronto. [16]

## **Can one cosmic enigma help solve another? Astrophysicists argue fast radio bursts could provide clues to dark matter**

Astrophysicists from the Johns Hopkins University have proposed a clever new way of shedding light on the mystery of dark matter, believed to make up most of the universe.

The irony is they want to try to pin down the nature of this unexplained phenomenon by using another, an obscure cosmic emanation known as "fast radio bursts."

In a paper published online by the journal Physical Review Letters the team of astrophysicists argues that these extremely bright and brief flashes of radio-frequency radiation can provide clues about whether a particular kind of ancient black hole is what makes up dark matter.

Julian Munoz, a Johns Hopkins graduate student and the paper's lead author, said fast radio bursts, or FRBs, provide a direct and specific way of detecting black holes of a specific mass, which are the suspect dark matter.

Munoz wrote the paper along with Ely D. Kovetz a post-doctoral fellow, Marc Kamionkowski, the William R. Kenan Jr. Professor of Physics and Astronomy, and Liang Dai, who completed his doctorate in astrophysics at Johns Hopkins last year. Dai is now a NASA Einstein Postdoctoral Fellow at the Institute for Advanced Study in Princeton.

The paper builds on a hypothesis offered in a paper published this spring by Munoz, Kovetz and Kamionkowski along with five Johns Hopkins colleagues. Also published in Physical Review Letters, that research made a speculative case that the collision of black holes detected early in the year by the Laser Interferometer Gravitational-Wave Observatory (LIGO) had actually revealed dark matter, a substance not yet identified but believed to make up 85 percent of the mass of the universe.

The earlier paper made what Kamionkowski called a "plausibility argument" that LIGO had found dark matter. The study took as a point of departure the fact that the objects detected by LIGO fit within the predicted range of mass of so-called "primordial" black holes. Unlike black holes that formed from imploded stars, primordial black holes are believed to have formed from the collapse of large expanses of gas during the birth of the universe.

The existence of primordial black holes has not been established with certainty, but they have been suggested before as a possible solution to the riddle of dark matter. With so little evidence of them to examine, the hypothesis had not gained a large following among scientists.

The LIGO findings, however, raised the prospect anew, especially as the objects detected in that experiment conform to the mass predicted for dark matter.

The Johns Hopkins team calculated how often these primordial black holes would form binary pairs, and eventually collide. Taking into account the size and elongated shape believed to characterize primordial black hole binary orbits, the team came up with a collision rate that conforms to the LIGO findings.

Key to the argument is that the black holes that LIGO detected fall within a range of 29 to 36 solar masses, meaning that many times the mass of the sun. The new paper considers the question of how to test the hypothesis that dark matter consists of black holes of roughly 30 solar masses.

That's where the fast radio bursts come in. First observed only a few years ago, these flashes of radio frequency radiation emit intense energy, but last only fractions of a second. Their origins are unknown, but believed to lie in galaxies outside the Milky Way.

If the speculation about their origins is true, Kamionkowski said, the radio waves would travel great distances before they're observed on Earth, perhaps passing a black hole. According to Einstein's theory of general relativity, the wave would be deflected when it passes a black hole. If it passes

close enough, it could be split into two rays shooting off in the same direction - creating two images from one source.

The new study shows that if the black hole has 30 times the mass of the sun, the two images will arrive a few milliseconds apart. If roughly 30-solar-mass primordial black holes are dark matter, there is a chance that any given fast radio burst will be deflected in this way and followed in a few milliseconds by an echo.

"The echoing of FRBs is a very direct probe of dark matter," Munoz said. "While gravitational waves might 'indicate' that dark matter is made of black holes, there are other ways to produce very-massive black holes with regular astrophysics, so it would be hard to convince oneself that we are detecting dark matter. However, gravitational lensing of fast radio bursts has a very unique signature, with no other astrophysical phenomenon that could reproduce it."

Kamionkowski said that while the probability for any such FRB echo is small, "it is expected that several of the thousands of FRBs to be detected in the next few years will have such echoes ... if black holes make up the dark matter."

So far, only about 20 fast radio bursts have been detected and recorded since 2001. The very sensitive instruments needed to detect them can look at only very small slices of the sky at a time, limiting the rate at which the bursts can be found. A new telescope expected to go into operation this year that seems particularly promising for spotting radio bursts is the Canadian Hydrogen Intensity Mapping Experiment. The joint project of the University of British Columbia, McGill University, the University of Toronto and the Dominion Radio Astrophysical Observatory stands in British Columbia.

"Once the thing is working up to their planned specifications, they should collect enough FRBs to begin the tests we propose," said Kamionkowski, estimating results could be available in three to five years. [15]

## **Dark Matter is Made of Black Holes Formed During First Second of Our Universe's Existence**

The nature of dark matter remains one of the most important unresolved issues in astrophysics. Scientists currently favor theoretical models that explain dark matter as an exotic massive particle, but so far searches have failed to turn up evidence these hypothetical particles actually exist. NASA is currently investigating this issue as part of its Alpha Magnetic Spectrometer and Fermi Gamma-ray Space Telescope missions.

Physicists have outlined several ways in which the hot, rapidly expanding universe could produce primordial black holes in the first thousandths of a second after the Big Bang. The older the universe is when these mechanisms take hold, the larger the black holes can be. And because the window for creating them lasts only a tiny fraction of the first second, scientists expect primordial black holes would exhibit a narrow range of masses.

Dark matter is a mysterious substance composing most of the material universe, now widely thought to be some form of massive exotic particle. An intriguing alternative view is that dark matter is made

of black holes formed during the first second of our universe's existence, known as primordial black holes. Now a scientist at NASA's Goddard Space Flight Center, suggests that this interpretation aligns with our knowledge of cosmic infrared and X-ray background glows and may explain the unexpectedly high masses of merging black holes detected last year.

"This study is an effort to bring together a broad set of ideas and observations to test how well they fit, and the fit is surprisingly good," said Kashlinsky. "If this is correct, then all galaxies, including our own, are embedded within a vast sphere of black holes each about 30 times the sun's mass."

In 2005, Kashlinsky led a team of astronomers using NASA's Spitzer Space Telescope to explore the background glow of infrared light in one part of the sky. The researchers reported excessive patchiness in the glow and concluded it was likely caused by the aggregate light of the first sources to illuminate the universe more than 13 billion years ago. Follow-up studies confirmed that this cosmic infrared background (CIB) showed similar unexpected structure in other parts of the sky.

In 2013, another study compared how the cosmic X-ray background (CXB) detected by NASA's Chandra X-ray Observatory compared to the CIB in the same area of the sky. The first stars emitted mainly optical and ultraviolet light, which today is stretched into the infrared by the expansion of space, so they should not contribute significantly to the CXB.

Yet the irregular glow of low-energy X-rays in the CXB matched the patchiness of the CIB quite well. The only object we know of that can be sufficiently luminous across this wide an energy range is a black hole. The research team concluded that primordial black holes must have been abundant among the earliest stars, making up at least about one out of every five of the sources contributing to the CIB.

On Sept. 14, gravitational waves produced by a pair of merging black holes 1.3 billion light-years away were captured by the Laser Interferometer Gravitational-Wave Observatory (LIGO) facilities in Hanford, Washington, and Livingston, Louisiana. This event marked the first-ever detection of gravitational waves as well as the first direct detection of black holes. The signal provided LIGO scientists with information about the masses of the individual black holes, which were 29 and 36 times the sun's mass, plus or minus about four solar masses. These values were both unexpectedly large and surprisingly similar.

"Depending on the mechanism at work, primordial black holes could have properties very similar to what LIGO detected," Kashlinsky explained. "If we assume this is the case, that LIGO caught a merger of black holes formed in the early universe, we can look at the consequences this has on our understanding of how the cosmos ultimately evolved."

In his new paper, published May 24 in *The Astrophysical Journal Letters*, Kashlinsky analyzes what might have happened if dark matter consisted of a population of black holes similar to those detected by LIGO. The black holes distort the distribution of mass in the early universe, adding a small fluctuation that has consequences hundreds of millions of years later, when the first stars begin to form.

For much of the universe's first 500 million years, normal matter remained too hot to coalesce into the first stars. Dark matter was unaffected by the high temperature because, whatever its nature, it primarily interacts through gravity. Aggregating by mutual attraction, dark matter first collapsed into

clumps called minihaloes, which provided a gravitational seed enabling normal matter to accumulate. Hot gas collapsed toward the minihaloes, resulting in pockets of gas dense enough to further collapse on their own into the first stars. Kashlinsky shows that if black holes play the part of dark matter, this process occurs more rapidly and easily produces the lumpiness of the CIB detected in Spitzer data even if only a small fraction of minihaloes manage to produce stars.

As cosmic gas fell into the minihaloes, their constituent black holes would naturally capture some of it too. Matter falling toward a black hole heats up and ultimately produces X-rays. Together, infrared light from the first stars and X-rays from gas falling into dark matter black holes can account for the observed agreement between the patchiness of the CIB and the CXB.

Occasionally, some primordial black holes will pass close enough to be gravitationally captured into binary systems. The black holes in each of these binaries will, over eons, emit gravitational radiation, lose orbital energy and spiral inward, ultimately merging into a larger black hole like the event LIGO observed.

"Future LIGO observing runs will tell us much more about the universe's population of black holes, and it won't be long before we'll know if the scenario I outline is either supported or ruled out," Kashlinsky said.

Kashlinsky leads science team centered at Goddard that is participating in the European Space Agency's Euclid mission, which is currently scheduled to launch in 2020. The project, named LIBRAE, will enable the observatory to probe source populations in the CIB with high precision and determine what portion was produced by black holes. [14]

## **"Unsolved Link" --Between Dark Matter and Supermassive Black Holes**

The research, released in February of 2015, was designed to address a controversy in the field. Previous observations had found a relationship between the mass of the central black hole and the total mass of stars in elliptical galaxies. However, more recent studies have suggested a tight correlation between the masses of the black hole and the galaxy's dark matter halo. It wasn't clear which relationship dominated.

In our universe, dark matter outweighs normal matter - the everyday stuff we see all around us - by a factor of 6 to 1. We know dark matter exists only from its gravitational effects. It holds together galaxies and galaxy clusters. Every galaxy is surrounded by a halo of dark matter that weighs as much as a trillion suns and extends for hundreds of thousands of light-years.

To investigate the link between dark matter halos and supermassive black holes, Bogdan and his colleague Andy Goulding (Princeton University) studied more than 3,000 elliptical galaxies. They used star motions as a tracer to weigh the galaxies' central black holes. X-ray measurements of hot gas surrounding the galaxies helped weigh the dark matter halo, because the more dark matter a galaxy has, the more hot gas it can hold onto.

They found a distinct relationship between the mass of the dark matter halo and the black hole mass - a relationship stronger than that between a black hole and the galaxy's stars alone.

This connection is likely to be related to how elliptical galaxies grow. An elliptical galaxy is formed when smaller galaxies merge, their stars and dark matter mingling and mixing together. Because the dark matter outweighs everything else, it molds the newly formed elliptical galaxy and guides the growth of the central black hole.

"In effect, the act of merging creates a gravitational blueprint that the galaxy, the stars and the black hole will follow in order to build themselves," explains Bogdan. The research relied on data from the Sloan Digital Sky Survey and the ROSAT X-ray satellite's all-sky survey.

The image at the top of the page is a composite image of data from NASA's Chandra X-ray Observatory (shown in purple) and Hubble Space Telescope (blue) of the giant elliptical galaxy, NGC 4649, located about 51 million light years from Earth. Although NGC 4649 contains one of the biggest black holes in the local Universe, there are no overt signs of its presence because the black hole is in a dormant state. The lack of a bright central point in either the X-ray or optical images shows that the supermassive black hole does not appear to be rapidly pulling in material towards its event horizon, nor generating copious amounts of light as it grows. Also, the very smooth appearance of the Chandra image shows that the hot gas producing the X-rays has not been disturbed recently by outbursts from a growing black hole.

So, the presence and mass of the black hole in NGC 4649, and other galaxies like it, has to be studied more indirectly by tracking its effects on stars and gas surrounding it. By applying a clever technique for the first time, scientists used Chandra data to measure a mass for the black hole of about 3.4 billion times that of the Sun. The new technique takes advantage of the gravitational influence the black hole has on the hot gas near the center of the galaxy. As gas slowly settles towards the black hole, it gets compressed and heated. This causes a peak in the temperature of the gas right near the center of the galaxy. The more massive the black hole, the bigger the temperature peak detected by Chandra. [13]

## **Dark Matter Black Holes Could Be Destroying Stars at the Milky Way's Center**

If dark matter comes in both matter and antimatter varieties, it might accumulate inside dense stars to create black holes. Dark matter may have turned spinning stars into black holes near the center of our galaxy, researchers say. There, scientists expected to see plenty of the dense, rotating stars called pulsars, which are fairly common throughout the Milky Way. Despite numerous searches, however, only one has been found, giving rise to the so-called "missing pulsar problem." A possible explanation, according to a new study, is that dark matter has built up inside these stars, causing the pulsars to collapse into black holes. (These black holes would be smaller than the supermassive black hole that is thought to lurk at the very heart of the galaxy.)

The universe appears to be teeming with invisible dark matter, which can neither be seen nor touched, but nonetheless exerts a gravitational pull on regular matter.

Scientists have several ideas for what dark matter might be made of, but none have been proved. A leading option suggests that dark matter is composed of particles called weakly interacting massive particles (WIMPs), which are traditionally thought to be both matter and antimatter in one. The

nature of antimatter is important for the story. When matter and antimatter meet they destroy one another in powerful explosions—so when two regular WIMPs collide, they would annihilate one another.

But it is also possible that dark matter comes in two varieties—matter and antimatter versions, just like regular matter. If this idea—called asymmetric dark matter—is true, then two dark matter particles would not destroy one another nor would two dark antimatter particles, but if one of each type met, the two would explode. In this scenario both types of dark matter should have been created in abundance during the big bang (just as both regular matter and regular antimatter are thought to have been created) but most of these particles would have destroyed one another, and those that remain now would be just the small excess of one type that managed to avoid being annihilated.

If dark matter is asymmetric, it would behave differently from the vanilla version of WIMPs. For example, the dense centers of stars should gravitationally attract nearby dark matter. If dark matter is made of regular WIMPs, when two WIMPs meet at the center of a star they would destroy one another, because they are their own antimatter counterparts. But in the asymmetric dark matter picture, all the existing dark matter left today is made of just one of its two types—either matter or antimatter. If two of these like particles met, they would not annihilate, so dark matter would simply build up over time inside the star. Eventually, the star's core would become too heavy to support itself, thereby collapsing into a black hole. This is what may have happened to the pulsars at the Milky Way's center, according to a study published November 3 in *Physical Review Letters*.

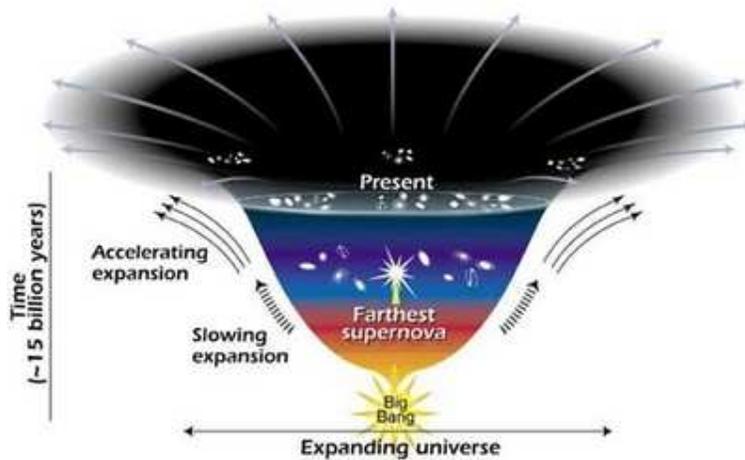
The scenario is plausible, says Raymond Volkas, a physicist at the University of Melbourne who was not involved in the study, but the missing pulsar problem might easily turn out to have a mundane explanation through known stellar effects. "It would, of course, be exciting to have dramatic direct astrophysical evidence for asymmetric dark matter," Volkas says. "Before believing an asymmetric dark matter explanation, I would want to be convinced that no standard explanation is actually viable."

The authors of the study, Joseph Bramante of the University of Notre Dame and Tim Linden of the Kavli Institute for Cosmological Physics at the University of Chicago, agree that it is too early to jump to a dark matter conclusion. For example, Linden says, maybe radio observations of the galactic center are not as thorough as scientists have assumed and the missing pulsars will show up with better searches. It is also possible some quirk of star formation has limited the number of pulsars that formed at the galactic center.

The reason nearby pulsars would not be as affected by asymmetric dark matter is that dark matter, of any kind, should be densest at the cores of galaxies, where it should congregate under the force of its own gravity. And even there it should take dark matter a very long time to accumulate enough to destroy a pulsar because most dark particles pass right through stars without interacting. Only on the rare occasions when one flies extremely close to a regular particle can it collide, and then it will be caught there. In normal stars the regular particles at the cores are not dense enough to catch many dark matter ones. But in superdense pulsars they might accumulate enough to do damage. "Dark matter can't collect as densely or as quickly at the center of regular stars," Bramante says, "but in pulsars the dark matter would collect into about a two-meter ball. Then that ball collapses into a black hole and it sucks up the pulsar."

If this scenario is right, one consequence would be that pulsars should live longer the farther away they are from the dark matter–dense galactic center. At the far reaches of the Milky Way, for example, pulsars might live to ripe old ages; near the core, however, pulsars would be created and then quickly destroyed before they could age. “Nothing astrophysical predicts a very strong relation between the age of a pulsar and its distance from the center of a galaxy,” Linden says. “You would really see a stunning effect if this scenario held.” It is also possible, although perhaps not probable, that astronomers could observe a pulsar collapse into a black hole, verifying the theory. But once the black hole is created, it would be near impossible to detect: As dark matter and black holes are each unobservable, black holes made of dark matter would be doubly invisible. [12]

## Everything You Need to Know About Dark Energy



For a long time, there were two main theories related to how our universe would end. These were the Big Freeze and the Big Crunch. In short, the Big Crunch claimed that the universe would eventually stop expanding and collapse in on itself. This collapse would result in...well...a big crunch (for lack of a better term). Think “the Big Bang”, except just the opposite. That’s essentially what the Big Crunch is. On the other hand, the Big Freeze claimed that the universe would continue expanding forever, until the cosmos becomes a frozen wasteland. This theory asserts that stars will get farther and farther apart, burn out, and (since there are no more stars being born) the universe will grow entirely cold and eternally black.

Now, we know that the expansion of the universe is not slowing. In fact, expansion is increasing. Edwin Hubble discovered that the farther an object was away from us the faster it was receding from us. In simplest terms, this means that the universe is indeed expanding, and this (in turn) means that the universe will likely end as a frozen, static wasteland. However, this can all change there is a reversal of dark energy’s current expansion effect. Sound confusing? To clear things up, let’s take a closer look at what dark energy is.

### How We Discovered That The Universe Is Expanding:

The accelerating expansion of the universe was discovered when astronomers were doing research on type 1a supernova events. These stellar explosions play a pivotal role in discerning the distance between two celestial objects because all type 1a supernova explosions are remarkably similar in brightness. So if we know how bright a star should be, we can compare the apparent luminosity with

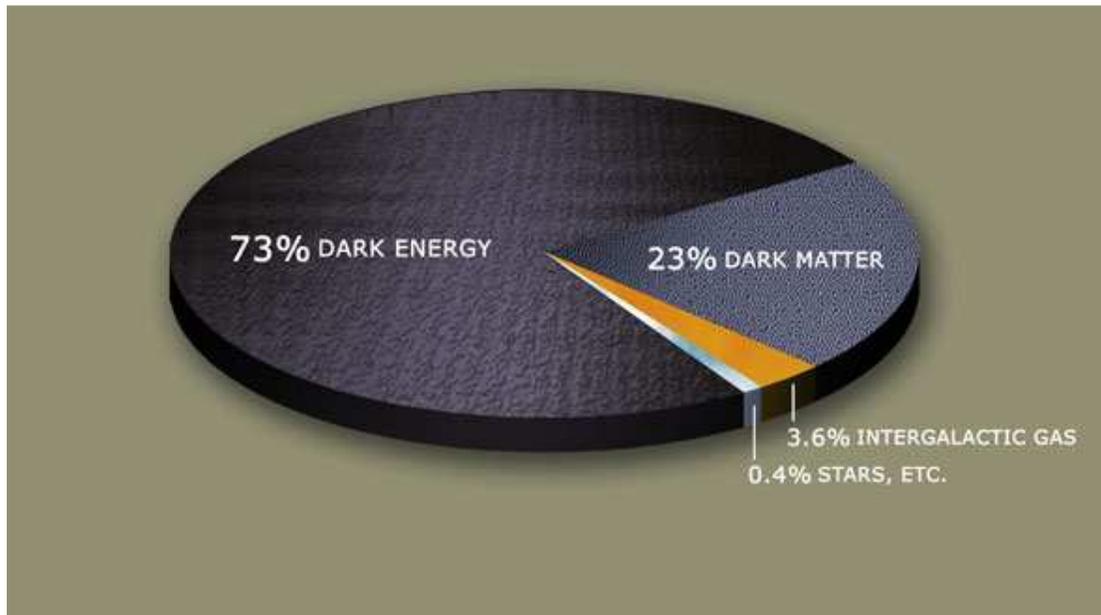
the intrinsic luminosity, and we get a reliable figure for how far any given object is from us. To get a better idea of how these work, think about headlights. For the most part, car headlights all have the same luminosity. So if one car's headlights are only 1/4 as bright as another car's, then one car is twice as far away as the other.

Incidentally, along with helping us make these key determinations about the locations of objects in the universe, these supernova explosions also gave us a sneak preview of one of the strangest observations ever made about the universe. To measure the approximate distance of an object, like a star, and how that distance has changed, astronomers analyze the spectrum of light emitted. Scientists were able to tell that the universe is increasing in expansion because, as the light waves make the incredibly long journey to Earth—billions of light-years away—the universe continues to expand. And as it expands, it stretches the light waves through a process called “redshifting” (the “red” is because the longest wavelength for light is in the red portion of the electromagnetic spectrum). The more redshifted this light is, the faster the expansion is going. Many years of painstaking observations (made by many different astronomers) have confirmed that this expansion is still ongoing and increasing because (as previously mentioned) the farther away an object is, the more redshifted it is, and (thus) the faster it is moving away from us.

### **How Do We Know That Dark Energy Is Real?**

The existence of dark energy is required, in some form or another, to reconcile the measured geometry of space with the total amount of matter in the universe. This is because of the largely successful Planck satellite and Wilkinson Microwave Anisotropy Probe (WMAP) observations. The satellite's observations of the cosmic microwave background radiation (CMB) indicate that the universe is geometrically flat, or pretty close to it.

All of the matter that we believe exists (based on scientific data and inferences) combines to make up just about 30% of the total critical density of the observed universe. If it were geometrically flat, like the distribution suggests from the CMB, critical density of energy and matter should equal 100%. WMAP's seven year sky survey, and the more sophisticated Planck Satellite 2 year survey, both are very strong evidence of a flat universe. Current measurements from Planck put baryonic matter (atoms) at about 4%, dark matter at 23%, and dark energy making up the remainder at 73%.



What's more, an experiment called Wiggle Z galaxy sky survey in 2011 further supported the dark energy hypothesis by its observations of large scale structures of the universe (such as galaxies, quasars, galaxy clusters, etc). After observing more than 200,000 galaxies (by looking at their redshift and measuring the baryonic acoustic oscillations), the survey quantitatively put the age of when the universe started increasing its acceleration at a timeline of 7 billion years. After this time in the universe, the expansion started to speed up.

### How Does Dark Energy Work?

According to Occam's razor (which proposes that the hypothesis with the fewest amount of assumptions is the correct one), the scientific community has favored Einstein's cosmological constant. Or in other words, the vacuum energy density of empty space, imbued with the same negative pressure value everywhere, eventually adds up with itself to speed up and suffuse the universe with more empty space, accelerating the entire process. This would kind of be similar to the energy pressure when talking about the "Casimir effect," which is caused by virtual particles in so-called "empty space", which is actually full of virtual particles coming in and out of existence.

### The Problem With Dark Energy:

Called "the worst prediction in all of physics," cosmologists predict that this value for the cosmological constant should be  $10^{-120}$  Planck units. According to dark energy equation, the parameter value for  $w$  (for pressure and density) must equal  $-1$ . But according to the latest findings from Pan-STARRS (short for Panoramic Survey Telescope and Rapid Response System), this value is in fact  $-1.186$ . Pan-STARRS derived this value from combining the data it obtained with the observational data from Planck satellite (which measured these very specific type 1a supernovas, 150 of them between 2009 and 2011, to be exact).

"If  $w$  has this value, it means that the simplest model to explain dark energy is not true," says Armin Rest of the Space Telescope Science Institute (STScI) in Baltimore. Armin Rest is the lead author of the Pan-STARRS team reporting these results to the astrophysics Web site arXiv (actual link to the paper) on October 22, 2013.

## The Significance:

What exactly does the discrepancy in the value in the cosmological constant mean for our understanding of dark energy? At first glance, the community can dismiss these results as experimental uncertainty errors. It is a well accepted idea that telescope calibration, supernova physics, and galactic properties are large sources of uncertainties. This can throw off the cosmological constant value. Several astronomers have immediately spoken up, denying the validity of the results. Julien Guy of University Pierre and Marie Curie in Paris say the Pan-STARRS researchers may have underestimated their systematic error by ignoring a source of uncertainty from supernova light-curve models. They have been in contact with the team, who are looking into that very issue, and others are combing over the meticulous work on the Pan-STARRS team to see if they can find any holes in the study.

Despite this, these results were very thorough and made by an experienced team, and work is already on its way to rule out any uncertainties. Not only that, but this is third sky survey to now produce experimental results that have dependencies for the pressure and density value of  $w$  being equal to 1, and it is starting to draw attention from cosmologists everywhere. In the next year or two, this result will be definitive, or it will be ruled out and disappear, with the cosmological constant continue being supported.

Well, if the cosmological constant model is wrong, we have to look at alternatives. That is the beauty of science, it does not care what we wish to be true: if something disagrees with observations, it's wrong. Plain and simple. [11]

## 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.

## Study Reveals Indications That Dark Matter is Being Erased by Dark Energy

Researchers in Portsmouth and Rome have found hints that dark matter, the cosmic scaffolding on which our Universe is built, is being slowly erased, swallowed up by dark energy.

The findings appear in the journal *Physical Review Letters*, published by the American Physical Society. In the journal cosmologists at the Universities of Portsmouth and Rome, argue that the latest astronomical data favors a dark energy that grows as it interacts with dark matter, and this appears to be slowing the growth of structure in the cosmos.

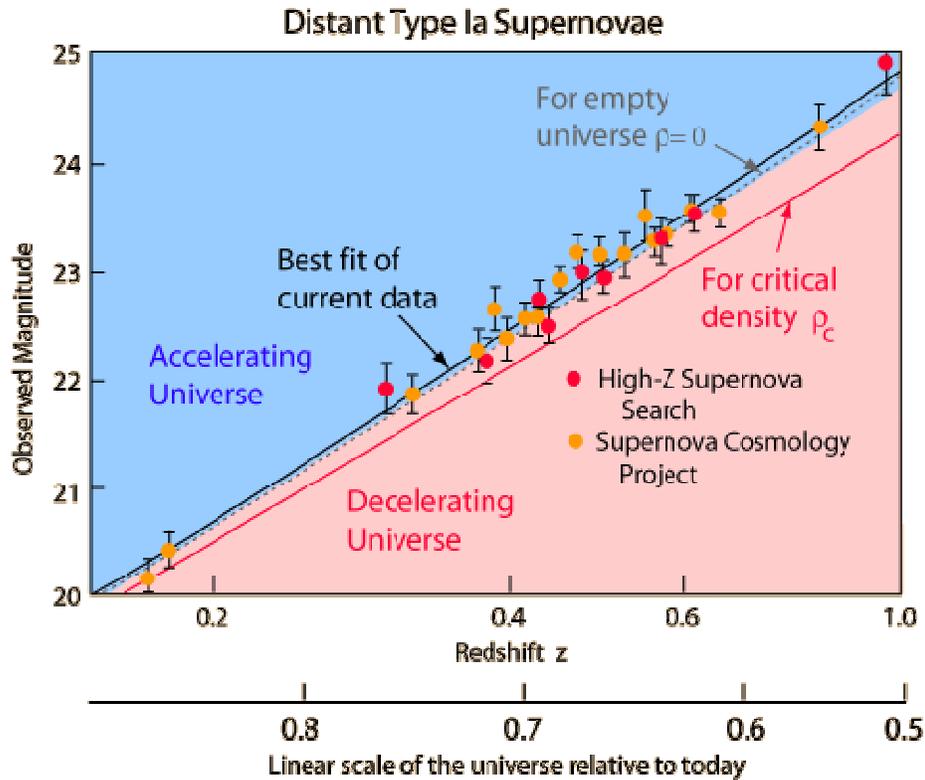
“Dark matter provides a framework for structures to grow in the Universe. The galaxies we see are built on that scaffolding and what we are seeing here, in these findings, suggests that dark matter is evaporating, slowing that growth of structure.”

Cosmology underwent a paradigm shift in 1998 when researchers announced that the rate at which the Universe was expanding was accelerating. The idea of a constant dark energy throughout space-time (the “cosmological constant”) became the standard model of cosmology, but now the Portsmouth and Rome researchers believe they have found a better description, including energy transfer between dark energy and dark matter. [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/mpc 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

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

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

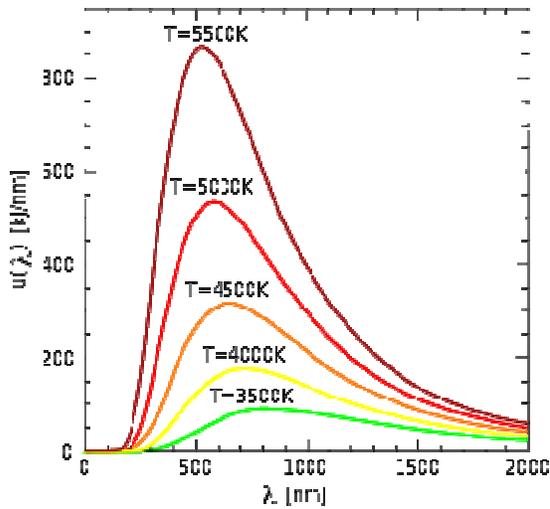
Dark matter is a type of matter hypothesized in astronomy and cosmology to account for a large part of the mass that appears to be missing from the universe. Dark matter cannot be seen directly with telescopes; evidently it neither emits nor absorbs light or other electromagnetic radiation at any significant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

If dark matter comes in both matter and antimatter varieties, it might accumulate inside dense stars to create black holes. It is also possible, although perhaps not probable, that astronomers could observe a pulsar collapse into a black hole, verifying the theory. But once the black hole is created, it would be near impossible to detect: As dark matter and black holes are each unobservable, black holes made of dark matter would be doubly invisible. [12]

For a long time, there were two main theories related to how our universe would end. These were the Big Freeze and the Big Crunch. In short, the Big Crunch claimed that the universe would eventually stop expanding and collapse in on itself. This collapse would result in...well...a big crunch (for lack of a better term). Think “the Big Bang”, except just the opposite. That’s essentially what the Big Crunch is. On the other hand, the Big Freeze claimed that the universe would continue expanding forever, until the cosmos becomes a frozen wasteland. This theory asserts that stars will get farther and farther apart, burn out, and (since there are no more stars being born) the universe will grow entirely cold and eternally black. [11]

Newly published research reveals that dark matter is being swallowed up by dark energy, offering novel insight into the nature of dark matter and dark energy and what the future of our Universe might be. [10]

The changing temperature of the Universe will change the proportionality of the dark energy and the corresponding dark matter by the Planck Distribution Law, giving the base of this newly published research.

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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