Nuclear Pasta in Neutron Stars

Nuclear pasta is incredibly dense, about 100 trillion times the density of water. It's impossible to study such an extreme material in the laboratory, says physicist Constança Providência of the University of Coimbra in Portugal who was not involved with the research. [24]

Researchers at Oregon State University have confirmed that last fall's union of two neutron stars did in fact cause a short gamma-ray burst. [23]

Quark matter – an extremely dense phase of matter made up of subatomic particles called quarks – may exist at the heart of neutron stars. [22]

When a massive astrophysical object, such as a boson star or black hole, rotates, it can cause the surrounding spacetime to rotate along with it due to the effect of frame dragging. [21]

Rotating black holes and computers that use quantum-mechanical phenomena to process information are topics that have fascinated science lovers for decades, but even the most innovative thinkers rarely put them together. [20]

If someone were to venture into one of these relatively benign black holes, they could survive, but their past would be obliterated and they could have an infinite number of possible futures. [19]

The group explains their theory in a paper published in the journal Physical Review Letters—it involves the idea of primordial black holes (PBHs) infesting the centers of neutron stars and eating them from the inside out. [18]

But for rotating black holes, there's a region outside the event horizon where strange and extraordinary things can happen, and these extraordinary possibilities are the focus of a new paper in the American Physical Society journal Physical Review Letters. [17]

Astronomers have constructed the first map of the universe based on the positions of supermassive black holes, which reveals the large-scale structure of the universe. [16]

Astronomers want to record an image of the heart of our galaxy for the first time: a global collaboration of radio dishes is to take a detailed look at the black hole which is assumed to be located there. [15]

A team of researchers from around the world is getting ready to create what might be the first image of a black hole. [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 bring born) the universe will grown 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.

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Author: George Rajna

Nuclear pasta in neutron stars may be the strongest material in the universe

A strand of spaghetti snaps easily, but an exotic substance known as nuclear pasta is an entirely different story.

Predicted to exist in ultradense dead stars called neutron stars, nuclear pasta may be the strongest material in the universe. Breaking the stuff requires 10 billion times the force needed to crack steel, for example, researchers report in a study accepted in *Physical Review Letters*.

“This is a crazy-big figure, but the material is also very, very dense, so that helps make it stronger,” says study coauthor and physicist Charles Horowitz of Indiana University Bloomington.

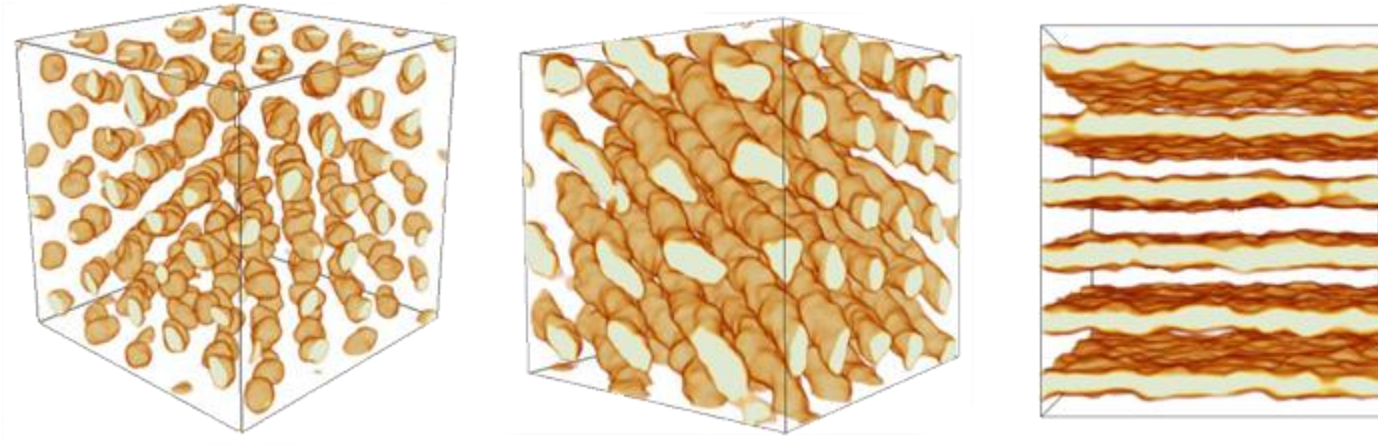
Neutron stars form when a dying star explodes, leaving behind a neutron-rich remnant that is squished to extreme pressures by powerful gravitational forces, resulting in materials with bizarre properties (*SN: 12/23/17*, *p. 7*).

About a kilometer below the surface of a neutron star, atomic nuclei are squeezed together so close that they merge into clumps of nuclear matter, a dense mixture of neutrons and protons. These as-yet theoretical clumps are thought to be shaped like blobs, tubes or sheets, and are named after their noodle look-alikes, including gnocchi, spaghetti and lasagna. Even deeper in the neutron star, the nuclear matter fully takes over. The burnt-out star’s entire core is nuclear matter, like one giant atomic nucleus.

Nuclear pasta is incredibly dense, about 100 trillion times the density of water. It’s impossible to study such an extreme material in the laboratory, says physicist Constança Providência of the University of Coimbra in Portugal who was not involved with the research.

Al dente

When atomic nuclei get squeezed together inside a neutron star, scientists think that globs of nuclear matter form into shapes reminiscent of various types of pasta, including gnocchi (left in these simulations of nuclear pasta), spaghetti (middle) and lasagna (right).



M.E. CAPLAN AND C.J. HOROWITZ/*REVIEWS OF MODERN PHYSICS* 2017

Instead, the researchers used computer simulations to stretch nuclear lasagna sheets and explore how the material responded. Immense pressures were required to deform the material, and the pressure required to snap the pasta was greater than for any other known material.

Earlier simulations had revealed that the outer crust of a neutron star was likewise vastly stronger than steel. But the inner crust, where nuclear pasta lurks, was unexplored territory. “Now, what [the researchers] see is that the inner crust is even stronger,” Providência says.

Physicists are still aiming to find real-world evidence of nuclear pasta. The new results may provide a glimmer of hope. Neutron stars tend to spin very rapidly, and, as a result, might emit ripples in spacetime called gravitational waves, which scientists could detect at facilities like the Advanced Laser Interferometer Gravitational-wave Observatory, or LIGO. But the spacetime ripples will occur only if a neutron star’s crust is lumpy — meaning that it has “mountains,” or mounds of dense material either on the surface or within the crust.

“The tricky part is, you need a big mountain,” says physicist Edward Brown of Michigan State University in East Lansing. A stiffer, stronger crust would support larger mountains, which could produce more powerful gravitational waves. But “large” is a relative term. Due to the intense gravity of neutron stars, their mountains would be a far cry from Mount Everest, rising centimeters tall, not kilometers. Previously, scientists didn’t know how large a mountain nuclear pasta could support.

“That’s where these simulations come in,” Brown says. The results suggest that nuclear pasta could support mountains tens of centimeters tall — big enough that LIGO could spot neutron stars’ gravitational waves. If LIGO caught such signals, scientists could estimate the mountains’ size, and confirm that neutron stars have superstrong materials in their crusts. [24]

Research shows short gamma-ray bursts do follow binary neutron star mergers

Researchers at Oregon State University have confirmed that last fall's union of two neutron stars did in fact cause a short gamma-ray burst.

The findings, published today in *Physical Review Letters*, represent a key step forward in astrophysicists' understanding of the relationship between binary neutron star mergers, gravitational waves and short gamma-ray bursts.

Commonly abbreviated as GRBs, gamma-ray bursts are narrow beams of electromagnetic waves of the shortest wavelengths in the electromagnetic spectrum. GRBs are the universe's most powerful electromagnetic events, occurring billions of light years from Earth and able to release as much energy in a few seconds as the sun will in its lifetime.

GRBs fall into two categories, long duration and short duration. Long GRBs are associated with the death of a massive star as its core becomes a black hole and can last from a couple of seconds to several minutes.

Short GRBs had been suspected to originate from the merger of two neutron stars, which also results in a new black hole—a place where the pull of gravity from super-dense matter is so strong that not even light can escape. Up to 2 seconds is the time frame of a short GRB.

The term neutron star refers to the gravitationally collapsed core of a large star; neutron stars are the smallest, densest stars known. According to NASA, neutron stars' matter is packed so tightly that a sugar-cube-sized amount of it weighs in excess of a billion tons.

In November 2017, scientists from U.S. and European collaborations announced they had detected an X-ray/gamma-ray flash that coincided with a blast of gravitational waves, followed by visible light from a new cosmic explosion called a kilonova.

Gravitational waves, a ripple in the fabric of time-space, were first detected in September 2015, a red-letter event in physics and astronomy that confirmed one of the main predictions of Albert Einstein's 1915 general theory of relativity.

"A simultaneous detection of gamma rays and gravitational waves from the same place in the sky was a major milestone in our understanding of the universe," said Davide Lazzati, a theoretical astrophysicist in the OSU College of Science. "The gamma rays allowed for a precise localization of where the gravitational waves were coming from, and the combined information from gravitational and electromagnetic radiation allows scientists to probe the binary neutron star system that's responsible in unprecedented ways."

Prior to Lazzati's latest research, however, it had been an open question as to whether the detected electromagnetic waves were "a short gamma-ray burst, or just a short burst of gamma rays—the latter being a different, weaker phenomenon.

In summer 2017, Lazzati's team of theorists had published a paper predicting that, contrary to earlier estimates by the astrophysics community, short gamma-ray bursts associated with the gravitational emission of binary neutron star coalescence could be observed even if the gamma-ray burst was not pointing directly at Earth.

"X- and gamma rays are collimated, like the light of a lighthouse, and can be easily detected only if the beam points toward Earth," Lazzati said. "Gravitational waves, on the other hand, are almost isotropic and can always be detected."

Isotropic refers to being evenly transmitted in all directions.

"We argued that the interaction of the short gamma-ray burst jet with its surroundings creates a secondary source of emission called the cocoon," Lazzati said. "The cocoon is much weaker than the main beam and is undetectable if the main beam points toward our instruments. However, it could be detected for nearby bursts whose beam points away from us."

In the months following the November 2017 gravitational wave detection, astronomers continued to observe the location from which the gravitational waves came.

"More radiation came after the burst of gamma rays: radio waves and X-rays," Lazzati said. "It was different from the typical short GRB afterglow. Usually there's a short burst, a bright pulse, bright X-ray radiation, then it decays with time. This one had a weak gamma-ray pulse, and the afterglow was faint, brightened very quickly, kept brightening, then turned off."

"But that behavior is expected when you're seeing it from an off-axis observation point, when you're not staring down the barrel of the jet," he said. "The observation is exactly the behavior we predicted. We haven't seen the murder weapon, we don't have a confession, but the circumstantial evidence is overwhelming. This is doing exactly what we expected an off-axis jet would do and is convincing proof that binary neutron star mergers and short gamma-ray bursts are indeed related to each other." [23]

Neutron stars cast light on quark matter

Quark matter – an extremely dense phase of matter made up of subatomic particles called quarks – may exist at the heart of neutron stars. It can also be created for brief moments in particle colliders on Earth, such as CERN's Large Hadron Collider. But the collective behaviour of quark matter isn't easy to pin down. In a colloquium this week at CERN, Aleksi Kurkela from CERN's Theory department and the University of Stavanger, Norway, explained how neutron-star data have allowed him and his colleagues to place tight bounds on the collective behaviour of this extreme form of matter.

Kurkela and colleagues used a neutron-star property deduced from the first observation by the LIGO and Virgo scientific collaborations of gravitational waves – ripples in the fabric of spacetime – emitted by the merger of two neutron stars. This property describes the stiffness of a star in response to stresses caused by the gravitational pull of a companion star, and is known technically as tidal deformability.

To describe the collective behaviour of quark matter, physicists generally employ equations of state, which relate the pressure of a state of matter to other state properties. But they have yet to come up with a unique equation of state for quark matter; they have derived only families of such equations. By plugging tidal-deformability values of the neutron stars observed by LIGO and Virgo into a derivation of a family of equations of state for neutron-star quark matter, Kurkela and colleagues were able to dramatically reduce the size of that equation family. Such a reduced family provides more stringent limits on the collective properties of quark matter, and more generally on nuclear matterat high densities, than were previously available.

Armed with these results, the researchers then flipped the problem around and used the quark-matter limits to deduce neutron-star properties. Using this approach, the team obtained the relationship between the radius and mass of a neutron star, and found that the maximum radius of a neutron star that is 1.4 times more massive than the Sun should be between about 10 and 14 km. [22]

How a particle may stand still in rotating spacetime

When a massive astrophysical object, such as a boson star or black hole, rotates, it can cause the surrounding spacetime to rotate along with it due to the effect of frame dragging. In a new paper, physicists have shown that a particle with just the right properties may stand perfectly still in a rotating spacetime if it occupies a "static orbit"—a ring of points located a critical distance from the center of the rotating spacetime.

The physicists, Lucas G. Collodel, Burkhard Kleihaus, and Jutta Kunz, at the University of Oldenburg in Germany, have published a paper in which they propose the existence of static orbits in rotating spacetimes in a recent issue of *Physical Review Letters*.

"Our work presents with extreme simplicity a long-ignored feature of certain spacetimes that is quite counterintuitive," Collodel told *Phys.org*. "General relativity has been around for a bit more than a hundred years now and it never ceases to amaze, and exploring the ways that different distributions of energy can warp the geometry of spacetime in a non-trivial way is key to a deeper understanding."

In their paper, the physicists identify two criteria for a particle to remain at rest with respect to a static observer in a rotating spacetime. First, the particle's angular momentum (basically its own rotation) must have just the right value so that it perfectly cancels out the rotation due to frame dragging. Second, the particle must be located precisely in the static orbit, a ring around the center of the rotating spacetime at which the particle is neither pulled toward the center nor pushed away.

A key point is that not all astrophysical objects with rotating spacetimes have static orbits, which in the future may help researchers distinguish between different types of astrophysical objects. As the physicists explain, in order to have a static orbit, a rotating spacetime's metric (basically the function that describes spacetimes in general relativity) must have a local minimum, which corresponds to the critical distance at which the static orbit is located. In a sense, a particle may then be "trapped" at rest in this local minimum.

The physicists identify several astrophysical objects that have static orbits, including boson stars (hypothetical stars made of bosonic matter that, like black holes, have immense gravity but do not emit light), wormholes, and hairy black holes (black holes with unique properties, such as additional charge). On the other hand, Kerr black holes (thought to be the most common kind of black hole) do not have metrics with local minima, and so do not have static orbits. So evidence for a static orbit could provide a way to distinguish between Kerr black holes and some of the less common objects with static orbits.

While the physicists acknowledge that it may be unlikely to expect a particle with just the right angular momentum to exist at just the right place in order to remain at rest in a rotating spacetime, it may still be possible to detect the existence of static orbits due to what happens nearby. Particles initially at rest near the static orbits are predicted to move more slowly than those located further away. So even if researchers never observe a particle standing still, they may observe slowly moving particles in the vicinity, indicating the existence of a nearby static orbit.

"Acknowledging the existence of the static ring helps us appreciate better what to plan and expect from future observations," Collodel said. "For instance, we can search for the ring in order to identify possible exotic objects, such as the boson star, or even assure with confidence (upon observing the ring) that an AGN [active galactic nucleus] is not powered by a Kerr black hole. In the future we plan to investigate how the presence of the ring might affect accretion disks, which are at this stage much easier to observe, and if it could shield some objects from infalling matter." [21]

Black holes, curved spacetime and quantum computing

Rotating black holes and computers that use quantum-mechanical phenomena to process information are topics that have fascinated science lovers for decades, but even the most innovative thinkers rarely put them together. Now, however, theoretical physicist Ovidiu Racorean from the General Direction of Information Technology, Bucharest, Romania suggests that powerful X-rays emitted near these black holes have properties that make them ideal information carriers for quantum computing. This work was recently published in *New Astronomy*.

The term 'black holes' is widely known, but not everyone knows exactly what they are. When stars come to the end of their lives, they can collapse in on themselves under their own weight, becoming denser and denser. Some may collapse into a point with essentially no volume and infinite density, with a gravitational field that not even light can escape from: this is a black hole. If the star that forms it rotates, as most stars do, the black hole will also spin.

Material that gets close to a rotating black hole but does not fall into it will aggregate into a circular structure known as an accretion disk. Powerful forces acting on accretion disks raise their temperature so they emit X-rays, which can act as carriers of quantum information.

The photons that make up the X-rays have two properties: polarisation and orbital angular momentum. Each of these can encode a qubit (quantum bit) of information, the standard information unit in quantum computing. "Lab-based researchers already use beam splitters and prisms to entangle these properties in X-ray photons and process quantum information," says

Racorean. "It now seems that the curvature of spacetime around a black hole will play the same role as this apparatus."

Thus far, however, this process is only a prediction. The final proof will come when the properties of X-rays near spinning black holes are observed, which could happen in the next decade.

Two space probes with the same mission will be launched around 2022: the Imaging X-ray Polarimetry Explorer (IXPE) by NASA, and the X-ray Imaging Polarimetry Explorer (XIPE) by the European Space Agency. These will investigate the polarisation of all X-rays found in space, including those emitted close to black holes. "If we find that the X-ray polarisation changes with distance from the black hole, with those in the central region being least polarised, we will have observed entangled states that can carry quantum information," says Racorean.

This topic may seem esoteric, but it could have practical applications. "One day, we may even be able to use rotating black holes as quantum computers by sending [X-ray] photons on the right trajectory around these ghostly astronomical bodies," Racorean concludes. Additionally, scientists believe that simulation of unusual states of matter will be an important early application of quantum computing, and there are few more unusual states of matter than those found in the vicinity of black holes. [20]

Some black holes erase your past

In the real world, your past uniquely determines your future. If a physicist knows how the universe starts out, she can calculate its future for all time and all space.

But a UC Berkeley mathematician has found some types of black holes in which this law breaks down. If someone were to venture into one of these relatively benign black holes, they could survive, but their past would be obliterated and they could have an infinite number of possible futures.

Such claims have been made in the past, and physicists have invoked "strong cosmic censorship" to explain it away. That is, something catastrophic – typically a horrible death – would prevent observers from actually entering a region of spacetime where their future was not uniquely determined. This principle, first proposed 40 years ago by physicist Roger Penrose, keeps sacrosanct an idea – determinism – key to any physical theory. That is, given the past and present, the physical laws of the universe do not allow more than one possible future.

But, says UC Berkeley postdoctoral fellow Peter Hintz, mathematical calculations show that for some specific types of black holes in a universe like ours, which is expanding at an accelerating rate, it is possible to survive the passage from a deterministic world into a non-deterministic black hole.

What life would be like in a space where the future was unpredictable is unclear. But the finding does not mean that Einstein's equations of general relativity, which so far perfectly describe the evolution of the cosmos, are wrong, said Hintz, a Clay Research Fellow.

"No physicist is going to travel into a black hole and measure it. This is a math question. But from that point of view, this makes Einstein's equations mathematically more interesting," he said. "This is a question one can really only study mathematically, but it has physical, almost philosophical implications, which makes it very cool."

"This … conclusion corresponds to a severe failure of determinism in general relativity that cannot be taken lightly in view of the importance in modern cosmology" of accelerating expansion, said his colleagues at the University of Lisbon in Portugal, Vitor Cardoso, João Costa and Kyriakos Destounis, and at Utrecht University, Aron Jansen.

As quoted by *Physics World*, Gary Horowitz of UC Santa Barbara, who was not involved in the research, said that the study provides "the best evidence I know for a violation of strong cosmic censorship in a theory of gravity and electromagnetism."

Hintz and his colleagues published a paper describing these unusual black holes last month in the journal *Physical Review Letters*.

A reasonably realistic simulation of falling into a black hole shows how space and time are distorted, and how light is blue shifted as you approach the inner or Cauchy horizon, where most physicists think you would be annihilated. However, a UC …more

Beyond the event horizon

Black holes are bizarre objects that get their name from the fact that nothing can escape their gravity, not even light. If you venture too close and cross the so-called event horizon, you'll never escape.

For small black holes, you'd never survive such a close approach anyway. The tidal forces close to the event horizon are enough to spaghettify anything: that is, stretch it until it's a string of atoms.

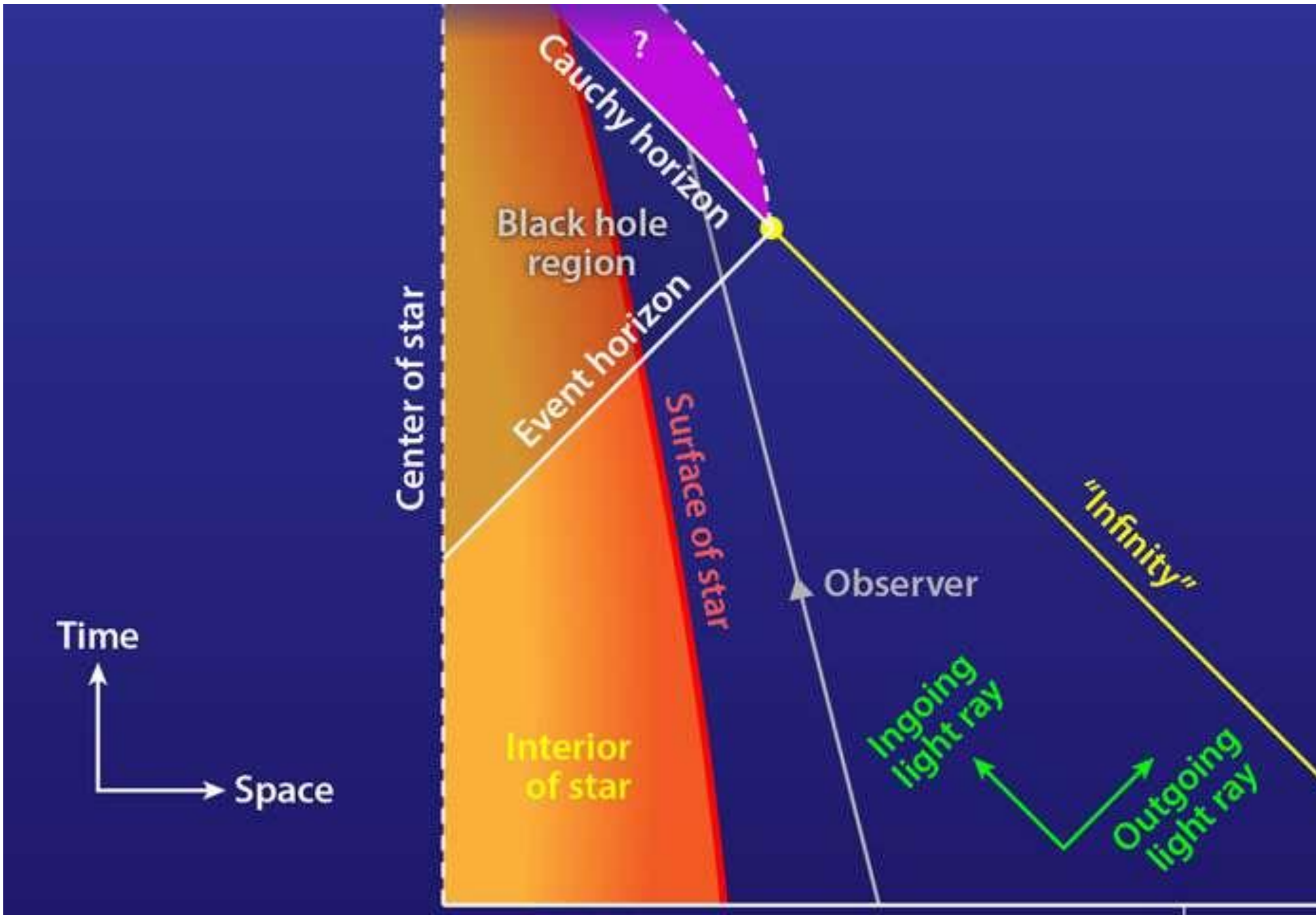
But for large black holes, like the supermassive objects at the cores of galaxies like the Milky Way, which weigh tens of millions if not billions of times the mass of a star, crossing the event horizon would be, well, uneventful.

Because it should be possible to survive the transition from our world to the black hole world, physicists and mathematicians have long wondered what that world would look like, and have turned to Einstein's equations of general relativity to predict the world inside a black hole. These equations work well until an observer reaches the center or singularity, where in theoretical calculations the curvature of spacetime becomes infinite.

Even before reaching the center, however, a black hole explorer – who would never be able to communicate what she found to the outside world – could encounter some weird and deadly milestones. Hintz studies a specific type of black hole – a standard, non-rotating black hole with an electrical charge – and such an object has a so-called Cauchy horizon within the event horizon.

The Cauchy horizon is the spot where determinism breaks down, where the past no longer determines the future. Physicists, including Penrose, have argued that no observer could ever pass through the Cauchy horizon point because they would be annihilated.

As the argument goes, as an observer approaches the horizon, time slows down, since clocks tick slower in a strong gravitational field. As light, gravitational waves and anything else encountering the black hole fall inevitably toward the Cauchy horizon, an observer also falling inward would eventually see all this energy barreling in at the same time. In effect, all the energy the black hole sees over the lifetime of the universe hits the Cauchy horizon at the same time, blasting into oblivion any observer who gets that far.



A spacetime diagram of the gravitational collapse of a charged spherical star to form a charged black hole. An observer traveling across the event horizon will eventually encounter the Cauchy horizon, the boundary of the region of spacetime …more

You can't see forever in an expanding universe

Hintz realized, however, that this may not apply in an expanding universe that is accelerating, such as our own. Because spacetime is being increasingly pulled apart, much of the distant universe will not affect the black hole at all, since that energy can't travel faster than the speed of light.

In fact, the energy available to fall into the black hole is only that contained within the observable horizon: the volume of the universe that the black hole can expect to see over the course of its existence. For us, for example, the observable horizon is bigger than the 13.8 billion light years we can see into the past, because it includes everything that we will see forever into the future. The accelerating expansion of the universe will prevent us from seeing beyond a horizon of about 46.5 billion light years.

In that scenario, the expansion of the universe counteracts the amplification caused by time dilation inside the black hole, and for certain situations, cancels it entirely. In those cases – specifically, smooth, non-rotating black holes with a large electrical charge, so-called Reissner-Nordström-de Sitter black holes – an observer could survive passing through the Cauchy horizon and into a non-deterministic world.

"There are some exact solutions of Einstein's equations that are perfectly smooth, with no kinks, no tidal forces going to infinity, where everything is perfectly well behaved up to this Cauchy horizon and beyond," he said, noting that the passage through the horizon would be painful but brief. "After that, all bets are off; in some cases, such as a Reissner-Nordström-de Sitter black hole, one can avoid the central singularity altogether and live forever in a universe unknown."

Admittedly, he said, charged black holes are unlikely to exist, since they'd attract oppositely charged matter until they became neutral. However, the mathematical solutions for charged black holes are used as proxies for what would happen inside rotating black holes, which are probably the norm. Hintz argues that smooth, rotating black holes, called Kerr-Newman-de Sitter black holes, would behave the same way.

"That is upsetting, the idea that you could set out with an electrically charged star that undergoes collapse to a black hole, and then Alice travels inside this black hole and if the black hole parameters are sufficiently extremal, it could be that she can just cross the Cauchy horizon, survives that and reaches a region of the universe where knowing the complete initial state of the star, she will not be able to say what is going to happen," Hintz said. "It is no longer uniquely determined by full knowledge of the initial conditions. That is why it's very troublesome."

He discovered these types of black holes by teaming up with Cardoso and his colleagues, who calculated how a black hole rings when struck by gravitational waves, and which of its tones and overtones lasted the longest. In some cases, even the longest surviving frequency decayed fast enough to prevent the amplification from turning the Cauchy horizon into a dead zone.

Hintz's paper has already sparked other papers, one of which purports to show that most well-behaved black holes will not violate determinism. But Hintz insists that one instance of violation is one too many.

"People had been complacent for some 20 years, since the mid '90s, that strong cosmological censorship is always verified," he said. "We challenge that point of view." [19]

New theory suggests heavy elements created when primordial black holes eat neutron stars from within

A team of researchers at the University of California has come up with a new theory to explain how heavy elements such as metals came to exist. The group explains their theory in a paper published in the journal Physical Review Letters—it involves the idea of primordial black holes (PBHs) infesting the centers of neutron stars and eating them from the inside out.

Space scientists are confident that they have found explanations for the origins of light and medium elements, but are still puzzling over how the heavier elements came to exist. Current theories suggest they most likely emerged during what researchers call an r-process—as in rapid. As part of the process, large numbers of neutrons would come under high densities, resulting in capture by atomic nuclei—clearly, an extreme environment. The most likely candidate for creating such an environment is a supernova, but there seem to be too few of them to account for the amounts of heavy elements that exist. In this new effort, the researchers offer a new idea. They believe it is possible that PBHs occasionally collide with neutron stars, and when that happens, the PBH becomes stuck in the center of the star. Once there, it begins pulling in material from the star's center.

PBHs are still just theory, of course. They are believed to have developed shortly after the Big Bang. They are also believed to roam through the galaxies and might be tied to dark matter. In this new theory, if a PBH happened to bump into a neutron star, it would take up residence in its center and commence pulling in neutrons and other material. That would cause the star to spin rapidly, which in turn would fling material from its outermost layer into space. The hurled material, the researchers suggest, would be subjected to an environment that would meet the requirements for an r-process, leading to the creation of heavy metals.

The theory assumes a certain number of such collisions could and did occur, and also that at least some small amount of dark matter is made up of black holes, as well. But it also offers a means for gathering real-world evidence that it is correct—by analyzing mysterious bursts of radio waves that could be neutron stars imploding after internal consumption by a PBH. [18]

Spinning Black Holes Could Create Clouds of Mass

Nothing, not even light, can come out of a black hole. At least, that’s the conventional wisdom, and it’s certainly true that—once the event horizon is crossed—there’s no going back. But for rotating black holes, there’s a region outside the event horizon where strange and extraordinary things can happen, and these extraordinary possibilities are the focus of a new paper in the American Physical Society journal Physical Review Letters.

The study reports simulations of a phenomenon called superradiance, where waves and particles passing in the vicinity of a spinning black hole can extract some of its rotational energy. The authors propose that hypothetical ultralight particles, with masses far lower than that of a neutrino, could get caught in orbit around such a black hole, sapping away some of its angular momentum and being accelerated in the process. Because energy, like the black hole's rotational energy, can give rise to matter, this phenomenon—termed a superradiant instability—converts the black hole’s angular momentum into a massive cloud of these ultra-light particles.

The reason these particles would have to be so much lighter than anything we've ever seen has to do with a quantity called the Compton wavelength. While electrons, protons, neutrinos, and other bits of matter usually behave like particles, they have wavelike properties as well—and just like with photons, the energy of the particles is related to their wavelength. The longer an electromagnetic wave is, the less energy it carries, and it's the same for massive particles; for instance, protons have a shorter Compton wavelength than electrons, because protons have more mass-energy.

For a particle to get caught in this special type of resonant, self-amplifying orbit around a spinning black hole, it has to have a Compton wavelength roughly equal to the size of the event horizon. Even the smallest black holes are at least 15 miles across, which means that each particle would have to carry an extremely small amount of mass-energy; for comparison, the Compton wavelength of an electron at rest is something like two trillionths of a meter.

Each individual particle would have an extremely small amount of energy, but the researchers' simulations showed that, for particles with the right mass around a black hole spinning with close to its maximum angular momentum, almost 10% of the black hole's initial effective mass could be extracted into the surrounding cloud. The process only stops when the black hole has spun down to the point where its rotation matches the rate at which the particles orbit it.

Although it's unclear how such a massive and energetic cloud of ultralight particles would interact with ordinary matter, the study's authors predict that we may be able to detect them via their gravitational wave signature. If a black hole that plays host to one of these clouds is involved in a collision that's detected by LIGO or some future gravitational wave detector, the cloud's presence might be visible in the gravitational wave signal produced by the merger.

Another possibility would be the direct detection of gravitational waves from this oscillating cloud of particles as they orbit the black hole. Gravitational waves are only produced by asymmetrical arrangements of mass in motion, so a spherical mass rotating wouldn't produce a strong signal. Neither does a geometric arrangement like the rings of Saturn. But the moon orbiting the earth, for example, does. (Richard Feynman's "Sticky Bead" thought experiment is a great tool for developing an intuition on this.) According to the new article, some scenarios could produce a highly coherent cloud of these particles—meaning they would orbit the black hole in phase, oscillating as a large clump that should release a noticeable gravitational wave signal (especially given that these clouds could theoretically contain up to ~10% of a black hole's initial effective mass).

The paper may have implications for our study of the supermassive black holes that lie at the center of nearly every galaxy, and might serve to draw a link between them and the swaths of dark matter that seem to envelop us. Although such ultralight particles are purely hypothetical for the moment, they could share many of the properties of dark matter, which means that looking for evidence of clouds like this is one possible way to test for the existence of certain dark matter candidates.

In fact, this finding combined with the observation of fast-spinning black holes has already helped rule out certain possibilities. Astronomers have observed black holes rotating at speeds close to their maximum angular velocity, which means they're clearly not susceptible to this kind of instability, or else they'd have spun out their energy into a massive cloud and slowed down. This means that, if we see a black hole spinning as fast as possible, ultralight particles with a Compton wavelength similar to that black hole's size must not exist.

While the cloud seemed to remain stable over time in the researchers’ simulations, other possibilities exist—one of which is a bosenova—a fusion of the words boson and supernova (as well as a pun on the musical style of bossa nova). In a bosenova scenario, the massive cloud would be violently ejected from the vicinity of the black hole all at once after reaching a certain critical point. [17]

Mapping super massive black holes in the distant universe

Astronomers have constructed the first map of the universe based on the positions of supermassive black holes, which reveals the large-scale structure of the universe.

The map precisely measures the expansion history of the universe back to when the universe was less than three billion years old. It will help improve our understanding of 'Dark Energy', the unknown process that is causing the universe's expansion to speed up.

The map was created by scientists from the Sloan Digital Sky Survey (SDSS), an international collaboration including astronomers from the University of Portsmouth.

As part of the SDSS Extended Baryon Oscillation Spectroscopic Survey (eBOSS), scientists measured the positions of quasars - extremely bright discs of matter swirling around supermassive black holes at the centres of distant galaxies. The light reaching us from these objects left at a time when the universe was between three and seven billion years old, long before the Earth even existed.

The map findings confirm the standard model of cosmology that researchers have built over the last 20 years. In this model, the universe follows the predictions of Einstein's General Theory of Relativity but includes components that, while we can measure their effects, we do not understand what is causing them.

Along with the ordinary matter that makes up stars and galaxies, Dark Energy is the dominant component at the present time, and it has special properties that mean that it causes the expansion of the universe to speed up.

Will Percival, Professor of Cosmology at the University of Portsmouth, who is the eBOSS survey scientist said: "Even though we understand how gravity works, we still do not understand everything - there is still the question of what exactly Dark Energy is. We would like to understand Dark Energy further. Not with alternative facts, but with the scientific truth, and surveys such as eBOSS are helping us to build up our understanding of the universe."

To make the map, scientists used the Sloan telescope to observe more than 147,000 quasars. These observations gave the team the quasars' distances, which they used to create a three-dimensional map of where the quasars are.

But to use the map to understand the expansion history of the universe, astronomers had to go a step further and measure the imprint of sound waves, known as baryon acoustic oscillations (BAOs), travelling in the early universe. These sound waves travelled when the universe was much hotter and denser than the universe we see today. When the universe was 380,000 years old, conditions changed suddenly and the sound waves became 'frozen' in place. These frozen waves are left imprinted in the three-dimensional structure of the universe we see today.

Using the new map, the observed size of the BAO can be used as a 'standard ruler' to measure distances in our universe. "You have metres for small units of length, kilometres or miles for distances between cities, and we have the BAO for distances between galaxies and quasars in cosmology," explained Pauline Zarrouk, a PhD student at the Irfu/CEA, University Paris-Saclay, who measured the distribution of the observed size of the BAO.

The current results cover a range of times where they have never been observed before, measuring the conditions when the universe was only three to seven billion years old, more than two billion years before the Earth formed.

The eBOSS experiment continues using the Sloan Telescope, at Apache Point Observatory in New Mexico, USA, observing more quasars and nearer galaxies, increasing the size of the map produced. After it is complete, a new generation of sky surveys will begin, including the Dark Energy Spectroscopic Instrument (DESI) and the European Space Agency Euclid satellite mission. These will increase the fidelity of the maps by a factor of ten compared with eBOSS, revealing the universe and Dark Energy in unprecedented detail. [16]

Astronomers hoping to directly capture image of a black hole

Astronomers want to record an image of the heart of our galaxy for the first time: a global collaboration of radio dishes is to take a detailed look at the black hole which is assumed to be located there. This Event Horizon Telescope links observatories all over the world to form a huge telescope, from Europe via Chile and Hawaii right down to the South Pole. IRAM's 30-metre telescope, an installation co-financed by the Max Planck Society, is the only station in Europe to be participating in the observation campaign. The Max Planck Institute for Radio Astronomy is also involved with the measurements, which are to run from 4 to 14 April initially.

At the end of the 18th century, the naturalists John Mitchell and Pierre Simon de Laplace were already speculating about "dark stars" whose gravity is so strong that light cannot escape from them. The ideas of the two researchers still lay within the bounds of Newtonian gravitational theory and the corpuscular theory of light. At the beginning of the 20th century, Albert Einstein revolutionized our understanding of gravitation - and thus of matter, space and time - with his General Theory of Relativity. And Einstein also described the concept of black holes.

These objects have such a large, extremely compacted mass that even light cannot escape from them. They therefore remain black – and it is impossible to observe them directly. Researchers have nevertheless proven the existence of these gravitational traps indirectly: by measuring gravitational waves from colliding black holes or by detecting the strong gravitational force they exert on their cosmic neighbourhood, for example. This force is the reason why stars moving at great speed orbit an invisible gravitational centre, as happens at the heart of our galaxy, for example.

It is also possible to observe a black hole directly, however. Scientists call the boundary around this exotic object, beyond which light and matter are inescapably sucked in, the event horizon. At the very moment when the matter passes this boundary, the theory states it emits intense radiation, a kind of "death cry" and thus a last record of its existence. This radiation can be registered as radio waves in the millimetre range, among others. Consequently, it should be possible to image the event horizon of a black hole.

The Event Horizon Telescope (EHT) is aiming to do precisely this. One main goal of the project is the black hole at the centre of our Milky Way, which is around 26,000 light years away from Earth and has a mass roughly equivalent to 4.5 million solar masses. Since it is so far away, the object appears at an extremely small angle.

One solution to this problem is offered by interferometry. The principle behind this technique is as follows: instead of using one huge telescope, several observatories are combined together as if they were small components of a single gigantic antenna. In this way scientists can simulate a telescope which corresponds to the circumference of our Earth. They want to do this because the larger the telescope, the finer the details which can be observed; the so-called angular resolution increases.

The EHT project exploits this observational technique and in April it is to carry out observations at a frequency of 230 gigahertz, corresponding to a wavelength of 1.3 millimetres, in interferometry mode. The maximum angular resolution of this global radio telescope is around 26 microarcseconds. This corresponds to the size of a golf ball on the Moon or the breadth of a human hair as seen from a distance of 500 kilometres!

These measurements at the limit of what is observable are only possible under optimum conditions, i.e. at dry, high altitudes. These are offered by the IRAM observatory, partially financed by the Max Planck Society, with its 30-metre antenna on Pico Veleta, a 2800-metre-high peak in Spain's Sierra
Nevada. Its sensitivity is surpassed only by the Atacama Large Millimeter Array (ALMA), which consists of 64 individual telescopes and looks into space from the Chajnantor plateau at an altitude of 5000 metres in the Chilean Andes. The plateau is also home to the antenna known as APEX, which is similarly part of the EHT project and is managed by the Max Planck Institute for Radio Astronomy.

The Max Planck Institute in Bonn is furthermore involved with the data processing for the Event Horizon Telescope. The researchers use two supercomputers (correlators) for this; one is located in Bonn, the other at the Haystack Observatory in Massachusetts in the USA. The intention is for the computers to not only evaluate data from the galactic black hole. During the observation campaign from 4 to 14 April, the astronomers want to take a close look at at least five further objects: the M 87, Centaurus A and NGC 1052 galaxies as well as the quasars known as OJ 287 and 3C279.

From 2018 onwards, a further observatory will join the EHT project: NOEMA, the second IRAM observatory on the Plateau de Bure in the French Alps. With its ten high-sensitivity antennas, NOEMA will be the most powerful telescope of the collaboration in the northern hemisphere. [15]

Scientists readying to create first image of a black hole

A team of researchers from around the world is getting ready to create what might be the first image of a black hole. The project is the result of collaboration between teams manning radio receivers around the world and a team at MIT that will assemble the data from the other teams and hopefully create an image.

The project has been ongoing for approximately 20 years as project members have sought to piece together what has now become known as the Event Horizon Telescope (EHT). Each of the 12 participating radio receiving teams will use equipment that has been installed for the project to record data received at a wavelength of 230GHz during April 5 through the 14th. The data will be recorded onto hard drives which will all be sent to MIT Haystack Observatory in Massachusetts, where a team will stitch the data together using a technique called very long baseline array interferometry—in effect, creating the illusion of a single radio telescope as large as the Earth. The black hole they will all focus on is the one believed to be at the center of the Milky Way galaxy—Sagittarius A*.

A black hole cannot be photographed, of course, light cannot reflect or escape from it, thus, there would be none to capture. What the team is hoping to capture is the light that surrounds the black hole at its event horizon, just before it disappears.

Sagittarius A* is approximately 26,000 light-years from Earth and is believed to have a mass approximately four million times greater than the sun—it is also believed that its event horizon is approximately 12.4 million miles across. Despite its huge size, it would still be smaller than a pin prick against our night sky, hence the need for the array of radio telescopes.

The researchers believe the image that will be created will be based on a ring around a black blob, but because of the Doppler effect, it should look to us like a crescent. Processing at Haystack is expected to take many months, which means we should not expect to see an image released to the press until sometime in 2018. [17]

"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 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.

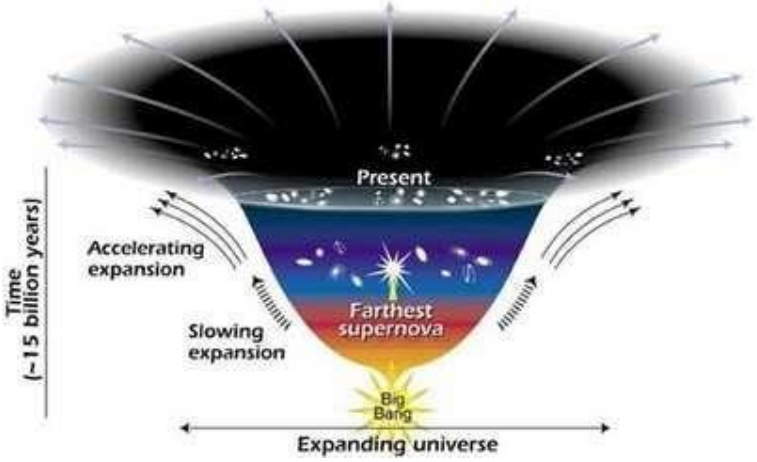
The scenario is plausible, says Raymond Volkas, a physicist at the University of Melbourne who was not involved in the study, but the missing pulsar problem might easily turn out to have a mundane explanation through known stellar effects. “It would, of course, be exciting to have dramatic direct astrophysical 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 bring born) the universe will grown 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:

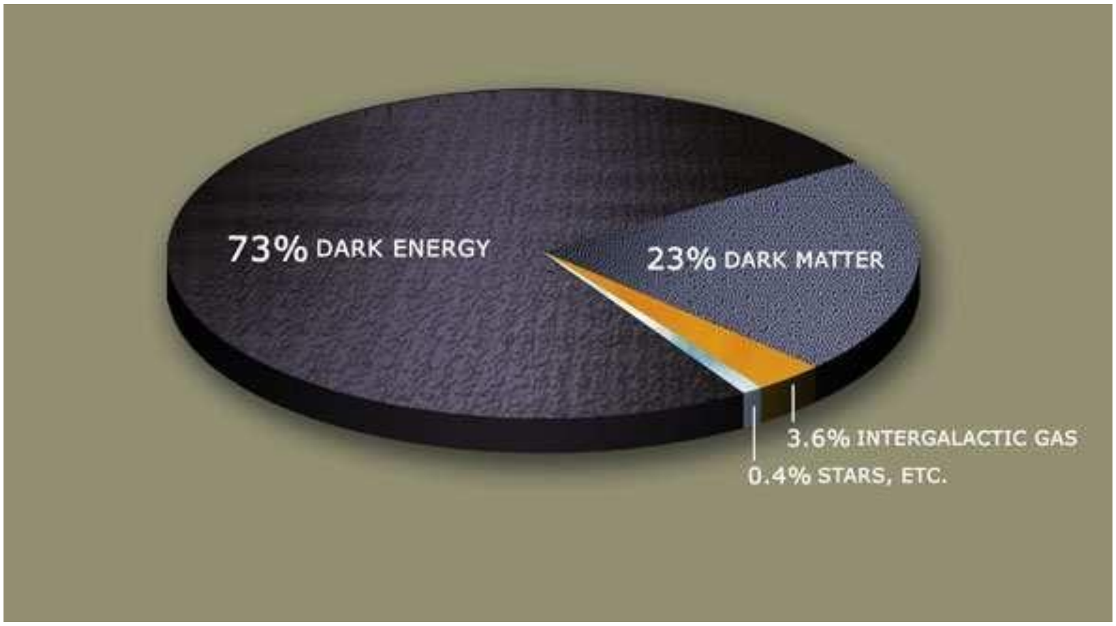
The accelerating expansion of the universe was discovered when astronomers were doing research on type 1a supernova events. These stellar explosions play a pivotal role in discerning the distance between two celestial objects because all type 1a supernova explosions are remarkably similar in brightness. 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 Wilkenson 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 socalled “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 glace, 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.

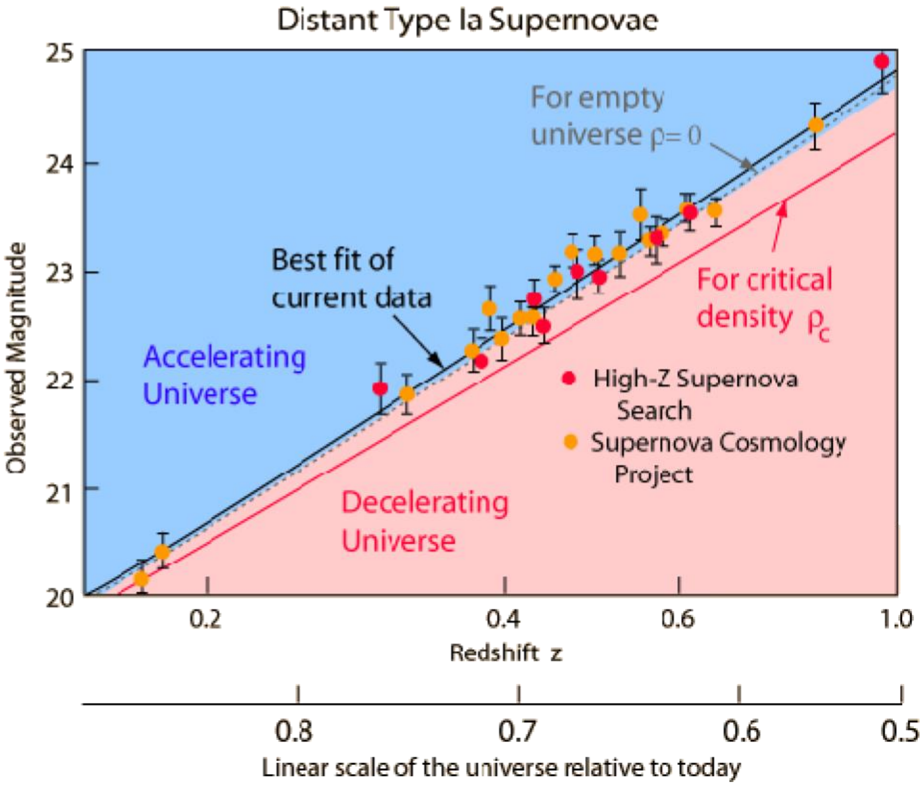
“Dark matter provides a framework for structures to grow in the Universe. The galaxies we see are built on that scaffolding and what we are seeing here, in these findings, suggests that dark matter is evaporating, slowing that growth of structure.”

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 spacetime (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 1a supernovae around z=.6, which with a Hubble constant of 71 km/s/mpc is a distance of about 5 billion light years.

Equation

The cosmological constant Λ appears in Einstein's field equation [5] in the form of

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

where *R* and *g* describe the structure of spacetime, *T* pertains to matter and energy affecting that structure, and *G* and *c* are conversion factors that arise from using traditional units of measurement.

When Λ is zero, this reduces to the original field equation of general relativity. When *T* is zero, the field equation describes empty space (the vacuum).

The cosmological constant has the same effect as an intrinsic energy density of the vacuum, ρ_{vac} (and an associated pressure). In this context it is commonly moved onto the right-hand side of the equation, and defined with a proportionality factor of 8π: $\Lambda = 8\pi\rho_{\text{vac}}$, where unit conventions of general relativity are used (otherwise factors of *G* and *c* would also appear). It is common to quote values of energy density directly, though still using the name "cosmological constant".

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

Explanatory models

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

Dark Matter and Energy

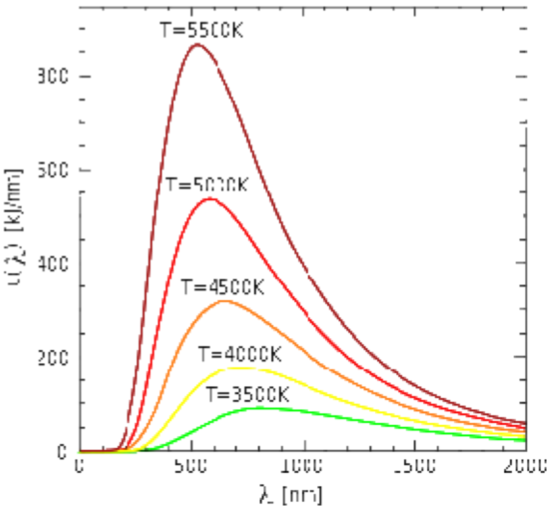
Dark matter is a type of matter hypothesized in astronomy and cosmology to account for a large part of the mass that appears to be missing from the universe. Dark matter cannot be seen directly with telescopes; evidently it neither emits nor absorbs light or other electromagnetic radiation at any significant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

Cosmic microwave background

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

Thermal radiation

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



Electromagnetic Field and Quantum Theory

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

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

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

The bridge between the classical and quantum theory is based on this intrinsic acceleration of the spin, explaining also the Heisenberg Uncertainty Principle. The particle – wave duality of the electric charges and the photon makes certain that they are both sides of the same thing. Basing the gravitational force on the accelerating Universe caused magnetic force and the Planck Distribution Law of the electromagnetic waves caused diffraction gives us the basis to build a Unified Theory of the physical interactions. [4]

Lorentz transformation of the Special Relativity

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

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

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

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

The Classical Relativistic effect

The moving charges are self maintain the electromagnetic field locally, causing their movement and this is the result of their acceleration under the force of this field.
In the classical physics the charges will distributed along the electric current so that the electric potential lowering along the current, by linearly increasing the way they take every next time period because this accelerated motion.

Electromagnetic inertia and Gravitational attraction

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

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

Since $E = hv$ and $E = mc^2$, $m = hv /c^2$ that is the m depends only on the v frequency. It means that the mass of the proton and electron are electromagnetic and the result of the electromagnetic induction, caused by the changing acceleration of the spinning and moving charge! It could be that the m_o inertial mass is the result of the spin, since this is the only accelerating motion of the electric charge. Since the accelerating motion has different frequency for the electron in the atom and the proton, they masses are different, also as the wavelengths on both sides of the diffraction pattern, giving equal intensity of radiation.

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

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

Electromagnetic inertia and mass

Electromagnetic Induction

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

Relativistic change of mass

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The frequency dependence of mass

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Electron – Proton mass rate

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

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

Gravity from the point of view of quantum physics

The Gravitational force

The gravitational attractive force is basically a magnetic force.

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

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

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

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

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

The Graviton

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

Conclusions

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 bring born) the universe will grown 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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