Supersymmetry by ATLAS

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Neutron stars consist of the densest form of matter known: a neutron star the size of Los Angeles can weigh twice as much as our sun. [24]

Supermassive black holes, which lurk at the heart of most galaxies, are often described as "beasts" or "monsters". [23]

The nuclei of most galaxies host supermassive black holes containing millions to billions of solar-masses of material. [22]

New research shows the first evidence of strong winds around black holes throughout bright outburst events when a black hole rapidly consumes mass. [21]

Chris Packham, associate professor of physics and astronomy at The University of Texas at San Antonio (UTSA), has collaborated on a new study that expands the scientific community's understanding of black holes in our galaxy and the magnetic fields that surround them. [20]

In a paper published today in the journal Science, University of Florida scientists have discovered these tears in the fabric of the universe have significantly weaker magnetic fields than previously thought. [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.

Contents

Author: George Rajna

New searches for supersymmetry presented by ATLAS experiment

The Standard Model is a remarkably successful but incomplete theory. Supersymmetry(SUSY) offers an elegant solution to the Standard Model's limitations, extending it to give each particle a heavy "superpartner" with different spin properties (an important quantum number distinguishing matter particles from force particles and the Higgs boson). For example, sleptons are the spin 0 superpartners of spin 1/2 electrons, muons and tau leptons, while charginos and neutralinos are the spin 1/2 counterparts of the spin 0 Higgs bosons (SUSY postulates a total of five Higgs bosons) and spin 1 gauge bosons.

If these superpartners exist and are not too massive, they will be produced at CERN's Large Hadron Collider (LHC) and could be hiding in data collected by the ATLAS detector. However, unlike most processes at the LHC, which are governed by strong force interactions, these superpartners would be created through the much weaker electroweak interaction, thus lowering their production rates. Further, most of these new SUSY particles are expected to be unstable. Physicists can only search for them by tracing their decay products—typically into a known Standard Model particle and the lightest supersymmetric particle (LSP), which could be stable and non-interacting, thus forming a natural dark matter candidate.

On 20 May, 2019, at the Large Hadron Collider Physics (LHCP) conference in Puebla, Mexico, and at the SUSY2019 conference in Corpus Christi, U.S., the ATLAS Collaboration presented numerous new searches for SUSY based on the full LHC Run 2 dataset (taken between 2015 and 2018), including two particularly challenging searches for electroweak SUSY. Both searches target particles that are produced at extremely low rates at the LHC, and decay into Standard Model particles that are themselves difficult to reconstruct. The large amount of data successfully collected by ATLAS in Run 2 provides a unique opportunity to explore these scenarios with new analysis techniques.

Search for the "stau"

Collider and astroparticle physics experiments have set limits on the mass of various SUSY particles. However, one important superpartner—the tau slepton, known as the stau—has yet to be found beyond the exclusion limit of around 90 GeV found at the LHC's predecessor at CERN, the Large Electron-Positron collider (LEP). A light stau, if it exists, could play a role in neutralino co-annihilation, moderating the amount of dark matter in the visible universe, which otherwise would be too abundant to explain astrophysical measurements.

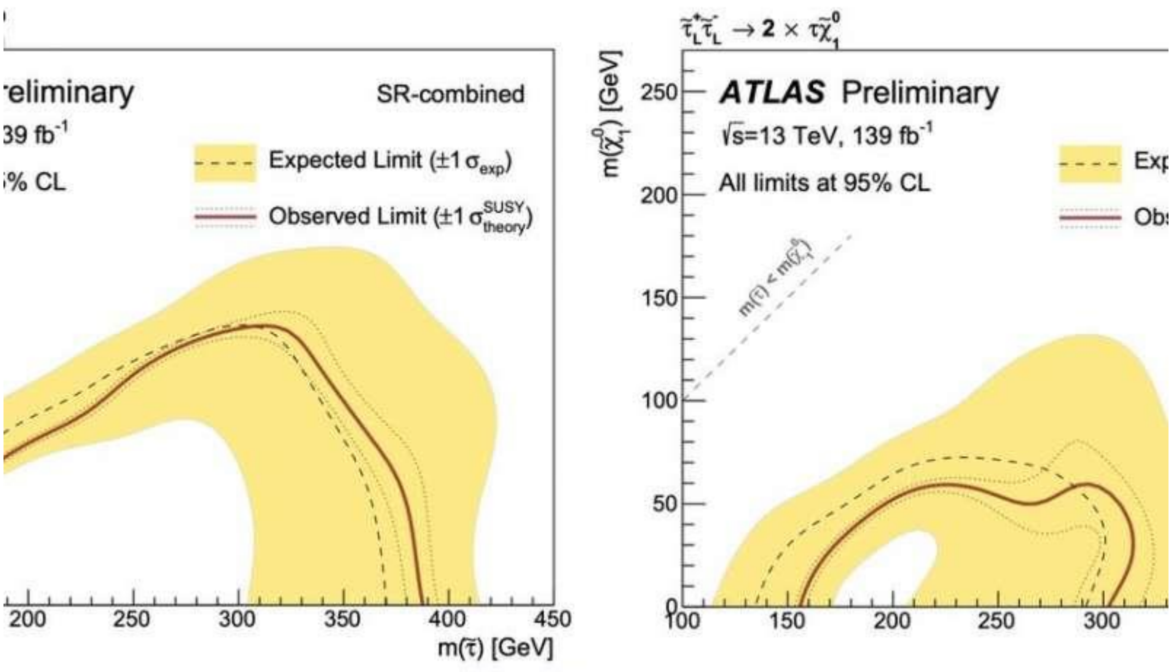


Figure 1: Left: Observed (expected) limits on the combined left and right stau pair production are shown by the red line (black dashed line). Right: Observed (expected) limits on the stau-left pair production are shown by the red line (black dashed line). The mass of stau is shown on the x-axis, while the mass of the LSP is shown on the y-axis. Credit: ATLAS Collaboration/CERN

The search for a light stau is experimentally challenging due to its extremely low production rate in LHC proton-proton collisions, requiring advanced techniques to reconstruct the Standard Model tau leptons it can decay into. In fact, during Run 1, only a narrow parameter region around a stau mass of 109 GeV and a massless lightest neutralino could be excluded by LHC experiments.

This first ATLAS Run 2 stau search targets the direct production of a pair of staus, each decaying into one tau lepton and one invisible LSP. Each tau lepton further decays into hadrons and an invisible neutrino. Signal events would thus be characterised by the presence of two sets of close-by hadrons and large missing transverse energy (ETmiss) originating from the invisible LSP and neutrinos. Events are further categorised into regions with medium and high ETmiss, to examine different stau mass scenarios.

The ATLAS data did not reveal hints for stau pair production and thus new exclusion limits were set on the mass of staus. These limits are shown in Figures 1 using different assumptions on the presence of both possible stau types (left and right, referring to the two different spin states of the tau partner lepton). The limits obtained are the strongest obtained so far in these scenarios.

Compressed search

One of the reasons physicists have yet to see charginos and neutralinos may be because their masses are compressed. In other words, they are very close to the mass of the LSP. This is expected in scenarios where these particles are higgsinos, the superpartners of the Higgs bosons.

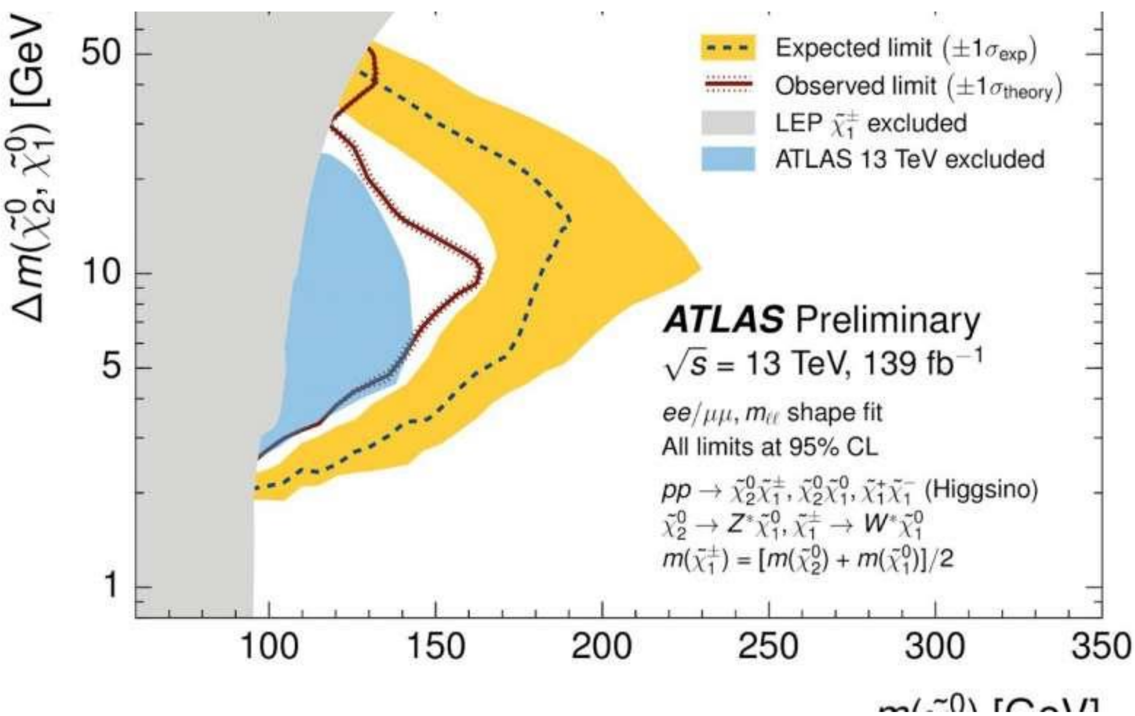


Figure 2: Observed (expected) limits on higgsino production are shown by the red line (blue dashed line). The mass of the produced higgsino is shown on the x-axis, while the mass difference to the LSP is shown on the y-axis. The grey region represents the models excluded by the LEP experiments; the blue region, the constraint from the previous ATLAS search for higgsinos. Credit: ATLAS Collaboration/CERN

Compressed higgsinos decay to pairs of electrons or muons with very low momenta. It is challenging to identify and reconstruct these particles in an environment with more than a billion high-energy collisions every second and a detector designed to measure high-energy particles—like trying to locate a whispering person in a very crowded and noisy room.

A new search for higgsinos utilises muons measured with unprecedentedly low—for ATLAS, so far—momenta. It also benefits from new and unique analysis techniques that allow physicists to look for higgsinos in areas that were previously inaccessible. For example, the search uses charged particle tracks, which can be reconstructed with very low momentum, as a proxy for one of the electrons or muons in the decay pair. Because of the small mass difference between the higgsinos, the mass of the electron/muon and track pair is also expected to be small.

Once again, no signs of higgsinos were found in this search. As shown in Figure 2, the results were used to extend constraints on higgsino masses set by ATLAS in 2017 and by the LEP experiments in 2004.

Overall, both sets of results place strong constraints on important supersymmetric scenarios, which will guide future ATLAS searches. Further, they provide examples of how advanced reconstruction techniques can help improve the sensitivity of new physics searches. [30]

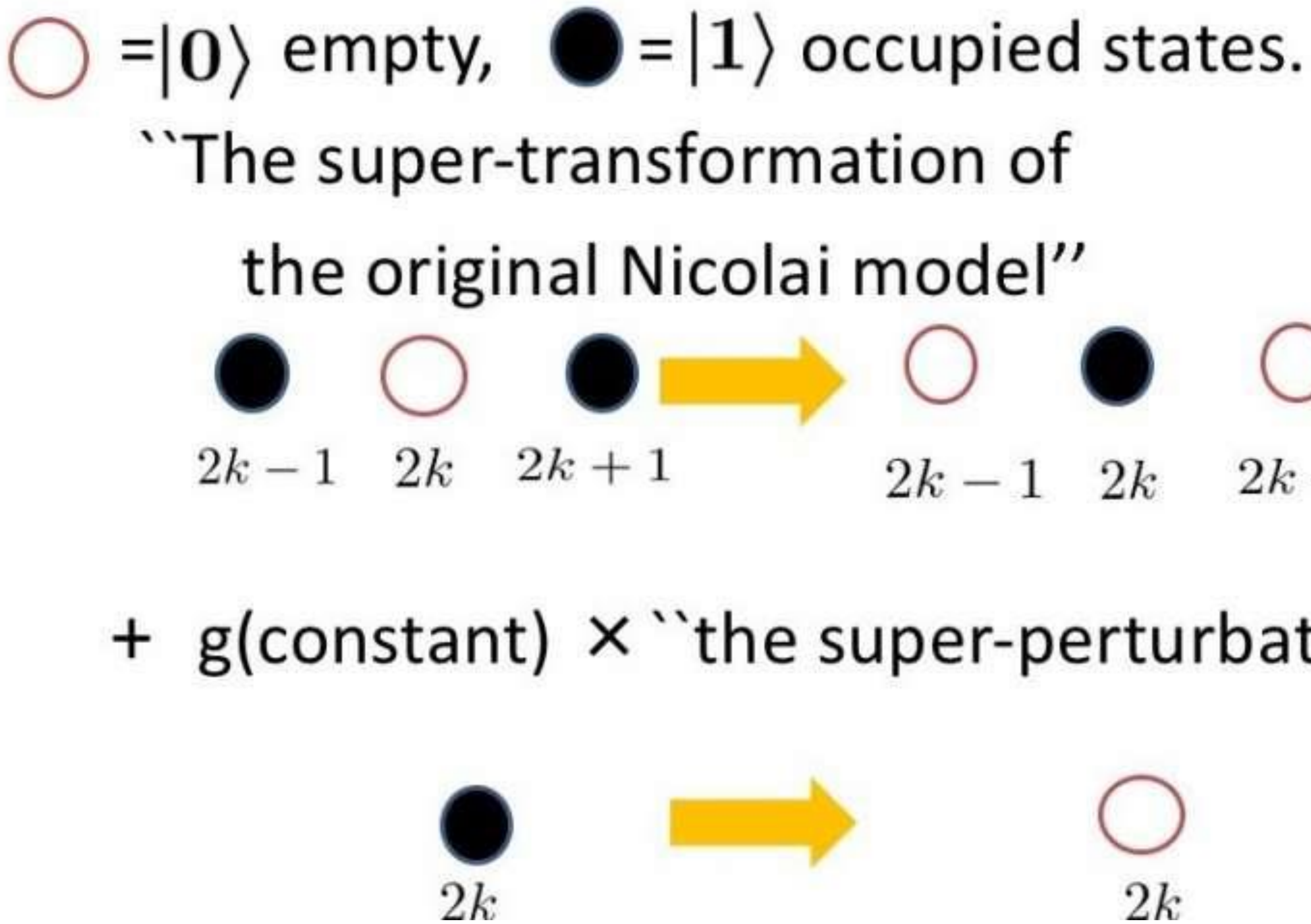
Breaking supersymmetry

The remarkable discoveries and theories of physicists since the 1930s have shown that all matter in the universe is made from a small number of basic building blocks called fundamental particles. However, this isn't the complete story. Supersymmetry is a hypothesis in high-energy physics that aims to fill some of the gaps.

Hajime Moriya from the Institute of Science and Engineering at Kanazawa University has shown that for an extended version of a pioneering model in non-relativistic supersymmetry-the Nicolai supersymmetric fermion lattice model-supersymmetry is broken for any nonzero value of a particular adjustable constant.

Supersymmetry predicts that two basic classes of fundamental particles, fermions and bosons, accompany each other in the same representation. Fermions, such as quarks, have a half a unit of spin, which is an intrinsic form of angular momentum, and bosons, such as photons, have zero, one, or two units of spin. In 1976, Hermann Nicolai proposed the fermion lattice model, which is made by fermions with no bosons, but supersymmetry is still satisfied.

Nicolai's original model was extended by Noriaki Sannomiya et al., who showed that for any nonzero adjustable constant $g \in \mathbb{R}$ on finite systems, supersymmetry breaks down. However, in the infinite-volume limit, they verified that supersymmetry breaks down only when $g > g0 \coloneqq 4/\pi$. "This restriction on parameter g seems to be technical," says Moriya, "and its meaning in terms of physics is unclear."



The extended Nicolai model. Credit: Kanazawa University

So, Moriya considered spinless fermions over an infinitely extended lattice and removed the restriction on g in the case of the infinite-volume limit. Moriya showed that for any nonzero g, the extended Nicolai model breaks supersymmetry dynamically. In addition, the original Nicolai model has been shown to have highly degenerate vacua, also known as supersymmetric ground states. Moriya also proved that for any nonzero g, the energy density of any homogeneous ground state for the extended Nicolai model is strictly positive.

"Even if supersymmetry is broken for any finite subsystem, it may be restored in the infinite-volume limit," explains Moriya, "as exemplified by some supersymmetry quantum mechanical model." So, Moriya showed that such a restoration does not occur for the extended Nicolai model. "The breaking of supersymmetry is verified in a rather model-independent manner by applying C*-algebraic techniques, which seem not well known in physics community," adds Moriya. [29]

Breaking the symmetry between fundamental forces

A fraction of a second after the Big Bang, a single unified force may have shattered. Scientists from the CDF and DZero Collaborations used data from the Fermilab Tevatron Collider to re-create the early universe conditions. They measured the weak mixing angle that controls the breaking of the unified force. Measuring this angle, a key parameter of the standard model, improves our understanding of the universe. The details of this symmetry breaking affect the nature of stars, atoms, and quarks. The new measurement of the weak mixing angle helps cement our understanding of the past, the character of what we observe today, and what we believe is in store for our future.

Previous determinations of the weak mixing angle from around the world disagreed. This allowed for the possibility that maybe there are new fundamental particles to be discovered. Or maybe there was a misunderstanding in how we think about the fundamental forces. This new combined result helps to resolve the discrepancy and reinforces our standard theory of the fundamental forces.

At present, scientists think that at the highest energies and earliest moments in time, all the fundamental forces may have existed as a single unified force. As the universe cooled just one microsecond after the Big Bang, it underwent a "phase transition" that transformed or "broke" the unified electromagnetic and weak forces into the distinct forces observed today.

The phase transition is similar to the transformation of water into ice. In this familiar case, we call the transition a change in a state of matter. In the early universe case, we call the transition "electroweak symmetry breaking."

In the same way that we characterize the water-to-ice phase transition as occurring when the temperature drops below 32 degrees, we characterize the amount of electroweak symmetry breaking with a parameter called the weak mixing angle, whose value has been measured by multiple experiments over the years.

By re-creating the early universe conditions in accelerator experiments, we have observed this transition and can measure the weak mixing angle that controls it. Our best understanding of the electroweak symmetry breaking involves the Higgs mechanism, and the Nobel Prize-winning Higgs boson discovery in 2012 was a milestone in our understanding.

For two decades, the most precise measurements of the weak mixing angle came from experiments that collided electrons and positrons at the European laboratory CERN and SLAC National Accelerator Laboratory in California, each of which gave different answers. Their results have been puzzling because the probability that the two measurements agree was less than one part in a thousand, suggesting the possibility of new phenomena—physics beyond the standard model. More input was needed.

Although the environment in Fermilab's proton-antiproton Tevatron Collider was much harsher than either CERN's or SLAC's collider, with many more background particles, the large and well-understood data sets of the Tevatron's CDF and DZero experiments allowed a new combined measurement that gives almost the same precision as that from electron-positron collisions. The new result lies about midway between the CERN and SLAC measurements and thus is in good agreement with both of them, as well as with the average of all previous direct and indirect measurements of weak mixing angle. Thus, Occam's razor suggests that those new particles and forces are not yet necessary to explain our observations and that our present particle physics and cosmology models remain good descriptors of the observed universe. [28]

Beryllium-7 atom helps to check inconsistencies in the Big Bang theory

Shortly after the Big Bang, radioactive atoms of the type beryllium-7, among others, came into being. Today, throughout the universe, they have long since decayed and do not occur naturally, in contrast to their decay product lithium. Now researchers at the Paul Scherrer Institute PSI have helped to better understand the first minutes of the universe: They collected artificially produced beryllium-7 and made it into a sample that could be investigated. The beryllium-7 was subsequently probed by researchers at CERN. The joint study by PSI, CERN, and 41 other research institutions addresses the so-called cosmological lithium problem: There is a marked discrepancy between the amount of lithium the Big Bang theory predicts should be in the universe and the amount of lithium actually observed. According to the present study, it now appears more likely that the cause of this cosmological lithium problem lies in the theoretical description of the origin of the universe. The scientific community will thus have to keep searching for a solution to the cosmological lithium problem. The researchers now published their results in the journal *Physical Review Letters*.

Researchers at the Paul Scherrer Institute have provided a hard-won puzzle piece towards a better understanding of the universe's origin: They were able to produce a sample of extremely rare and short-lived atoms of the isotope beryllium-7. Subsequently, at CERN, it was possible to probe this beryllium-7 – in practice, its interaction with neutrons – with far more precision than ever before.

Since through its radioactive decay beryllium-7 becomes lithium-7, studying it can help to crack a fundamental problem of the Big Bang theory: The theory predicts a three to four times greater amount of lithium in the universe than actual measurements show. This so-called cosmological lithium problem is one of the last great riddles of the current theory of the origin of the universe, because for all other elements produced shortly after the Big Bang, the theory conforms well to the measured data.

Virtually all of the present-day lithium-7 in the universe comes from the decayed beryllium-7 which in turn was formed shortly after the big bang. Thus the researchers were looking into the question of whether there might have been less beryllium in the beginning than previously believed, which could clear up the cosmological lithium problem. One of the last possibilities still open to be checked was the so-called neutron capture cross-section of beryllium-7. This value predicts the probability that a beryllium-7 atomic nucleus will capture a free neutron and subsequently decay.

"The neutron capture cross-section of beryllium-7 was last measured, imprecisely by comparison, around 50 years ago," explains PSI researcher Dorothea Schumann, head of the Isotope and Target Chemistry research group. This key figure should now be investigated at CERN, more accurately than ever before. The beryllium-7 sample needed for this was provided by the PSI researchers.

Years of preparation and test runs

The production and measurement of the beryllium-7 sample was like a one-time theatre performance, for which the researchers had to do around three years of preparatory work and test runs. Beryllium-7 disappears so rapidly through radioactive decay that its quantity is reduced by half roughly every 53 days. Therefore everything had to be in position before the actual run at both PSI and CERN, as well as for transportation between the two institutions – so that as little time as possible would elapse between the production of the sample and the measurement.

The idea for the experiment arose in 2012. PSI researcher Schumann knew that she could extract the rare beryllium-7 from the cooling water of the Swiss Spallation Neutron Source SINQ, which is operated at PSI for experiments with neutron beams.

"Here at PSI, with SINQ and the other large research facilities, we have unique sources for harvesting rare radioactive isotopes," Schumann says. "For the researchers who operate and use these facilities, these isotopes are a by-product – but for many other research institutions, they are very useful and urgently needed." Like gold prospectors, Schumann and her research group extract these rare isotopes. "And then we act as an interface to other researchers outside PSI who are interested in enriched samples of these isotopes."

CERN is interested

Researchers at CERN showed interest in obtaining a sample of beryllium-7. "With it, they knew they could tackle the cosmological lithium problem," Schumann explains.

So Schumann and her team set about the preparations: Within PSI, Schumann made contact with the scientists and engineers who operate SINQ. A special filter system meeting the isotope researchers' specifications was connected to the cooling water of SINQ, which could collect material containing a suitable amount of beryllium-7 over a period of about three weeks. "To the layperson, our filter can be thought of as being quite similar to the familiar household filter for tap water," says Stephan Heinitz, scientist in the research group of Schumann.

Then, among other things, the materials gathered in this way had to be chemically separated. "This requires special expertise – which luckily we have in my research group," Schumann says. Nevertheless, this procedure took another week and had to be carried out, for protection against radiation from the material, in a so-called hot cell – a laboratory set up for the manipulation of radioactive materials.

A transport weight of 800 kilograms

From there, the concentrated sample of beryllium-7 had to be transferred into a suitable mount, and this in turn into an apparatus about the size of a cooking pot, which met specifications for use in the experimental setup at CERN. "The apparatus as well as the radiation-proof containers for transferring the material – all of it was custom-made," relates Emilio Maugeri, another researcher in Schumann's group.

Finally, arrangements had to be organised and approved to transport a heavy load of radioactive materials from PSI to CERN.

"The actual sample that we delivered to CERN contained only a few millionths of a gram of beryllium-7," Schumann explains. "But the required shielding brought the transport weight up to 800 kilograms."

Within the critical time period, everything succeeded according to plan. The CERN researchers were able to carry out the experiment with the PSI sample and determine the thus-far insufficiently known neutron capture cross-section of beryllium-7.

The cosmological lithium problem remains unsolved

The CERN and PSI scientists and their collaborators from 41 other research institutions were especially interested in a particular decay path of beryllium-7: the probability of a process by which an atomic nucleus of beryllium-7 traps a free neutron – that is, an elementary particle with no net charge. At the same time one of the protons leaves the beryllium nucleus. Thus, since the nucleus now contains one less proton (and one more neutron), the beryllium atom transforms itself into an atom of the element lithium: It becomes lithium-7. The so-called neutron capture cross-section – that is, the probability of this entire process – depends on the energy that the free neutron has. Therefore the researchers took advantage of the possibility at CERN to vary the energy of the neutrons, and they made a measurement series for a wide range of neutron energies.

Yet these latest measurements of the neutron capture cross-section have not solved the cosmological lithium problem. Schumann says, "With the new measurements, the CERN researchers were able to determine the neutron capture cross-section so precisely that it now is clear: The cosmological lithium problem can't be solved in this way; it still persists. The scientific community will have to keep looking for an explanation." [27]

Researchers find new way of exploring the afterglow from the Big Bang

Researchers have developed a new way to improve our knowledge of the Big Bang by measuring radiation from its afterglow, called the cosmic microwave background radiation. The new results predict the maximum bandwidth of the universe, which is the maximum speed at which any change can occur in the universe.

The cosmic microwave background (CMB) is a reverberation or afterglow left from when the universe was about 300,000 years old. It was first discovered in 1964 as a ubiquitous faint noise in radio antennas. In the past two decades, satellite-based telescopes have started to measure it with great accuracy, revolutionizing our understanding of the Big Bang.

Achim Kempf, a professor of applied mathematics at the University of Waterloo and Canada Research Chair in the Physics of Information, led the work to develop the new calculation, jointly with Aidan Chatwin-Davies and Robert Martin, his former graduate students at Waterloo.

"It's like video on the Internet," said Kempf. "If you can measure the CMB with very high resolution, this can tell you about the bandwidth of the universe, in a similar way to how the sharpness of the video image on your Skype call tells you about the bandwidth of your internet connection."

The study appears in a special issue of *Foundations of Physics* dedicated to the material Kempf presented to the Vatican Observatory in Rome last year. The international workshop entitled, Black Holes, Gravitational Waves and Spacetime Singularities, gathered 25 leading physicists from around the world to present, collaborate and inform on the latest theoretical progress and experimental data on the Big Bang. Kempf's invitation was the result of this paper in *Physical Review Letters*.

"This kind of work is highly collaborative," said Kempf, also an affiliate at the Perimeter Institute for Theoretical Physics. "It was great to see at the conference how experimentalists and theoreticians inspire each other's work."

While at the Vatican, Kempf and other researchers in attendance also shared their work with the Pope.

"The Pope has a great sense of humor and had a good laugh with us on the subject of dark matter," said Kempf.

Teams of astronomers are currently working on even more accurate measurements of the cosmic microwave background. By using the new calculations, these upcoming measurements might reveal the value of the universe's fundamental bandwidth, thereby telling us also about the fastest thing that ever happened, the Big Bang. [26]

Hubble Space Telescope confirms mismatch in cosmic expansion

A group of astronomers in the US has made a new and more precise measurement of the universe's rate of expansion by using NASA's Hubble Space Telescope (HST) to observe miniscule shifts in the apparent position of stars known as Cepheid variables. The group's results reinforce a disagreement over the value of the Hubble constant as measured directly and as calculated via observations of primordial radiation – a disparity, say the researchers, which likely points to new physics.

In his pioneering work of the 1920s Edwin Hubble observed that galaxies further away from Earth recede more quickly, as measured by their red-shifted radiation. This implied that the universe was expanding, and that expansion has since been described by the Hubble constant, which states how many kilometres per second faster galaxies move apart from one another for every megaparsec, or 3.25::million light-years, of distance between them.

Measurements of the famous constant were imprecise until the launch of the HST, which allowed scientists to pin down a value of 72±8 in 2001. That result has since been improved upon by Adam Riess at the Space Telescope Science Institute in Baltimore, US, and colleagues, who from 2009 have reported a series of improved values thanks to data from the HST's Wide Field Camera 3 – arriving at 73.2±1.8 in 2016.

Shortly after the Big Bang

The Hubble constant can also be deduced by calculating the universe's rate of expansion shortly after the Big Bang using data from the cosmic microwave background (CMB) and then extrapolating to the present assuming certain properties of dark matter and dark energy. This CMB-derived value is in clear disagreement with the HST value. In 2016, the European Space Agency's CMB-measuring Planck satellitereported a value of 66.9±0.6, implying that the cosmos ought to be expanding more slowly today than is observed.

The mismatch has now been reinforced by new results from Riess and colleagues, who have looked at Cepheid variables. These stars pulsate at a rate fixed by their intrinsic brightness, which means their apparent brightness can be used to work out how far away they are. They can also be used to calibrate the (known) brightness of type 1a supernovae, given that both are visible in some nearby galaxies, with such supernovae in turn being used to establish the distance to further-flung galaxies. This process creates a billion-parsec long “distance ladder” used to calculate the Hubble constant.

Since astronomers must initially calibrate the Cepheids themselves, the first (and hardest) rung on the ladder involves independently measuring the distance to these objects. This is done using parallax, the apparent change in position of an object compared to the background stars as seen by a moving observer. The distance between object and observer is obtained via triangulation – combining the (apparent) change in the object’s position with that of the observer.

More distant objects

Previously, Riess and colleagues had measured the parallax of Cepheids lying just a few hundred light-years from Earth. They have now turned their attention to more distant objects – eight Cepheids situated between 6000-12,000 light-years away (although still within the Milky Way). These are particularly well suited to the distance ladder since they pulsate at the lower rates characteristic of Cepheids found together with type 1a supernovae in other galaxies.

Riess’s group measures parallax by observing each Cepheid twice a year, with the Earth (and with it the HST) on opposite sides of its orbit around the Sun. But because this change in position is tiny compared to the distance separating the stars and Earth, the parallax is correspondingly minute – amounting to just one hundredth the size of a single pixel on Wide Field Camera 3.

To get around this problem, rather than taking a snapshot of each Cepheid the researchers instead scanned the camera across it as the HST moved in its orbit, so spreading the light over 4000 pixels. As Riess explains, doing so overcomes the fact that each pixel is like a well and fills up after receiving a certain number of photons. “You get more photons altogether by scanning,” he says.

“Conspiracy of errors”

Using this approach, the group calculate a Hubble constant of 73.5 ±1.7, which is a 3.7σ disagreement with the Planck results. This means that there is a 1 in 5000 chance that the disparity is a statistical fluke. What is more, Riess points out, over the last couple of years independent probes have confirmed both the distance-ladder and CMB results – gravitational lensing and baryon acoustic oscillations, respectively. “There would have to be a series of systematic errors in techniques that have nothing to do with each other,” he says. “And once you start to think about a conspiracy of errors that doesn’t look very likely.”

Dating the universe

As to what new physics might be responsible for the disparity, Riess says that it could be caused by hypothetical “sterile neutrinos”, interactions with dark matter, or a strengthening over time of dark energy (which accelerates the universe’s expansion). He adds that the team will use the HST to measure more Cepheids and that data from ESA’s Gaia satellite, due to be released in April, should contain parallax information from around 200 such stars – thus further reducing the Hubble constant’s uncertainty and potentially narrowing down the source of the disparity, he says.

Chuck Bennett of Johns Hopkins University in the US, who led the team on Planck’s predecessor WMAP, is cautious. He says that the new result “places even further stress on some potential cracks in the standard model of cosmology” but argues that more work needs to be done.

“Unfortunately, none of the commonly discussed potential modifications to the standard model seem to solve the tensions while also being compelling.” [25]

A better way to model stellar explosions

Neutron stars consist of the densest form of matter known: a neutron star the size of Los Angeles can weigh twice as much as our sun. Astrophysicists don't fully understand how matter behaves under these crushing densities, let alone what happens when two neutron stars smash into each other or when a massive star explodes, creating a neutron star.

One tool scientists use to model these powerful phenomena is the "equation of state." Loosely, the equation of state describes how matter behaves under different densities and temperatures. The temperatures and densities that occur during these extreme events can vary greatly, and strange behaviors can emerge; for example, protons and neutrons can arrange themselves into complex shapes known as nuclear "pasta."

But, until now, there were only about 20 equations of state readily available for simulations of astrophysical phenomena. Caltech postdoctoral scholar in theoretical astrophysics Andre da Silva Schneider decided to tackle this problem using computer codes. Over the past three years, he has been developing open-source software that allows astrophysicists to generate their own equations of state. In a new paper in the journal Physical Review C, he and his colleagues describe the code and demonstrate how it works by simulating supernovas of stars 15 and 40 times the mass of the sun.

The research has immediate applications for researchers studying neutron stars, including those analyzing data from the National Science Foundation's Laser Interferometer Gravitational-wave Observatory, or LIGO, which made the first detection of ripples in space and time, known as gravitational waves, from a neutron star collision, in 2017. That event was also witnessed by a cadre of telescopes around the world, which captured light waves from the same event.

"The equations of state help astrophysicists study the outcome of neutron star mergers—they indicate whether a neutron star is 'soft' or 'stiff,' which in turn determines whether a more massive neutron star or a black hole forms out of the collision," says da Silva Schneider. "The more observations we have from LIGO and other light-based telescopes, the more we can refine the equation of state—and update our software so that astrophysicists can generate new and more realistic equations for future studies."

More detailed information can be found in the *Physical Review C* study, titled "Open-source nuclear equation of state framework based on the liquid-drop model with Skyrme interaction." [24]

How we discovered the strange physics of jets from supermassive black holes

Supermassive black holes, which lurk at the heart of most galaxies, are often described as "beasts" or "monsters". But despite this, they are pretty much invisible. To show that they are there at all, astronomers typically have to measure the speed of the clouds of gas orbiting those regions.

But these objects can sometimes make their presence felt through the creation of powerful jets, which carry so much energy that they are able to outshine all the light emitted by the stars of the host galaxy. We know that these "relativistic jets" are two streams of plasma (matter made up of electrically charged particles despite having no overall charge), travelling in opposite directions at velocities very close to the speed of light.

The physics governing these cosmic fountains, however, has long been a bit of a mystery. Now our new paper, published in *Nature Astronomy*, has shed some light on the causes of their extraordinary appearance.

What makes relativistic jets exceptional is their impressive stability: they emerge from a region as big as the event horizon (the point of no return) of the supermassive black hole and propagate far enough to break out from their host galaxy while maintaining their shape for a long time. This corresponds to a length that is a billion times their initial radius – to put this in perspective, imagine a water fountain coming out of a 1cm wide hose pipe and remaining undisrupted for 10,000km.

Once the jets propagate at great distances from their origin, though, they lose their coherence and develop extended structures which often resemble plumes or lobes. This indicates that the jets undergo some sort of instability, strong enough to completely change their appearance.

A jet dichotomy

The first astrophysical jet was discovered in 1918 by the American astronomer Heber Curtis, who noticed "a curious straight ray … apparently connected with the nucleus by a thin line of matter" in giant elliptical galaxy M87.

Artist's concept shows a galaxy with a supermassive black hole at its core. Credit: NASA

In the 1970s, two astronomers at the University of Cambridge, Bernie Fanaroff and Julia Riley, studied a large ensemble of jets. They found that they could be split into two classes: those containing jets whose brightness decreases with distance from their origin, and those that become brighter at their edges. Overall, the latter type is about 100 times more luminous than the former. They both have slightly different shape at the end – the first is like a flaring plume and the second resembles a thin turbulent stream. Exactly why there are two different kinds of jets is still an area of active research.

As jet material gets accelerated by the black hole, it reaches velocities up to 99.9% of the speed of light. When an object moves so fast, time dilates – in other words, the flow of time at the jet, measured by an external observer slows down as predicted by Einstein's special relativity. Because of this, it takes longer for the different parts of the jet to communicate with each other – as in interacting or influencing each other – while travelling away from their source. This, effectively, protects the jet from being disrupted.

However, this loss of communication does not last forever. When the jet is ejected from the black hole, it expands sideways. This expansion makes the pressure inside the jet drop, while the pressure of the gas surrounding the jet does not decrease as much. Eventually, the external gas pressure overtakes the pressure inside the jet and makes the flow contract by squeezing it. At this point, the parts of the jet come so close that they can communicate again. If some parts of the jet have become unstable in the meantime, they can now exchange this information and instabilities can spread to affect the entire beam.

The process of expansion and contraction of the jets has another important consequence: the flow is no longer along straight lines but on curved paths. Curved flows are likely to suffer from "centrifugal instability" which means they start creating whirlpool-like structures called vortices. This was not considered to be critical for astrophysical jets until recently.

Indeed, our detailed computer simulations show that relativistic jets become unstable because of the centrifugal instability, which initially only affects their interface with the galactic gas. Once they have contracted due to external pressure though, this instability spreads throughout the entire jet. The instability is so catastrophic that the jet does not survive beyond this point and gives place to a turbulent plume.

Putting this result in perspective we get a better insight of the impressive stability of astrophysical jets. It can also help explain the enigmatic two classes of jets discovered by Fanaroff and Riley – it all depends on how far from its galaxy a jet becomes unstable. We made computer simulations of what these jets would look like based on our new understanding of the physics of these cosmic beams, and they very much resemble the two classes we see in astronomical observations.

There's a lot more to learn about the gigantic, wild beasts residing at the centre of galaxies. But little by little, we are unravelling their mystery and showing that they are indeed perfectly law-abiding and predictable. [23]

The structure of an active galactic nucleus

The nuclei of most galaxies host supermassive black holes containing millions to billions of solar-masses of material. The immediate environments of these black holes typically include a tori of dust and gas and, as material falls toward the black hole, the gas radiates copiously at all wavelengths. Although the models for these active galactic nuclei (AGN) work reasonably well, it is difficult to obtain direct evidence of the inner structures of AGN because they are so far away and their dimensions are thought to be only tens to hundreds of light-years.

CfA astronomer David Wilner and his colleagues used the ALMA millimeter telescope facility to study the nearest AGN, Arp 220, which is thought to be particularly active after having recently undergone a merger with another galaxy. The two merging nuclei are about 1200 light-years apart, and each has a rotating disk of molecular gas a few hundred light-years in scale. Vigorous star formation is evident in the region as well as at least one molecular outflow inferred from the large velocities seen. But there are numerous unresolved structural issues about these inner regions, including how gas flows to, from, and between the two mergering nuclei and precisely which subregions are responsible for the dominant luminosity sources. The astronomers used these high-resolution millimeter observations to tackle these questions because thick dust, which blocks much of the view at shorter wavelengths, is relatively transparent in these bands.

The scientists are able to resolve the continuum emission structure of the two individual nuclei into its dust and hot gas components. They report that each nucleus has two concentric components, the larger ones probably associated with starburst disks somehow activated by the black holes; the smaller ones, roughly 60 light-years in size, contribute as much as 50% of the submillimeter luminosity, nearly double the previous estimates. In fact one of the cores alone has a luminosity of about three trillion suns, larger than the entire emission of other AGN, not to mention the relatively small volume that is producing it. The cores in Arp220 also seems to have a third, extended linear feature that could represent the outflow seen before only in the spectroscopic (velocity) data. [22]

Study shows first evidence of winds outside black holes throughout their mealtimes

New research shows the first evidence of strong winds around black holes throughout bright outburst events when a black hole rapidly consumes mass.

The study, published in *Nature*, sheds new light on how mass transfers to black holes and how black holes can affect the environment around them. The research was conducted by an international team of researchers, led by scientists in the University of Alberta's Department of Physics.

Using data from three international space agencies spanning 20 years, the scientists used new statistical techniques to study outbursts from stellar-mass black hole X-ray binary systems. Their results show evidence of consistent and strong winds surrounding black holes throughout outbursts. Until now, strong winds had only been seen in limited parts of these events.

"Winds must blow away a large fraction of the matter a black hole could eat,'' described Bailey Tetarenko, PhD student and lead author on the study. "In one of our models, the winds removed 80 per cent of the black hole's potential meal."

Depending on their size, stellar-mass black holes have the capacity to consume everything within a 3 to 150 kilometre radius. "Not even light can escape from this close to a black hole," explained Gregory Sivakoff, associate professor of physics and co-author. Other, much larger black holes, called supermassive black holes, appear to have affected the formation of entire galaxies. "But even supermassive black holes are smaller than our solar system. While they are small, black holes can have surprisingly large effects," explained Sivakoff.

So, what exactly causes these winds in space? For now, it remains a mystery. "We think magnetic fields play a key role. But we'll need to do a great deal of future investigation to understand these winds," explained Craig Heinke, associate professor of physics and co-author.

"Strong disk winds traced throughout outbursts in black-hole X-ray binaries" will be published online January 22 in *Nature*. [21]

New research challenges existing models of black holes

Chris Packham, associate professor of physics and astronomy at The University of Texas at San Antonio (UTSA), has collaborated on a new study that expands the scientific community's understanding of black holes in our galaxy and the magnetic fields that surround them.

"Dr. Packham's collaborative work on this study is a great example of the innovative research happening now in physics at UTSA. I'm excited to see what new research will result from these findings," said George Perry, dean of the UTSA College of Sciences and Semmes Foundation Distinguished University Chair in Neurobiology.

Packham and astronomers lead from the University of Florida observed the magnetic field of a black hole within our own galaxy from multiple wavelengths for the first time. The results, which were a collective effort among several researchers, are deeply enlightening about some of the most mysterious objects in space.

A black hole is a place in space where gravity pulls so strongly that even light cannot escape its grasp. Black holes usually form when a massive star explodes and the remnant core collapses under the force of intense gravity. As an example, if a star around 3 times more massive than our own Sun became a black hole, it would be roughly the size of San Antonio. The black hole Packham and his collaborators featured in their study, which was recently published in *Science*, contains about 10 times the mass of our own sun and is known as V404 Cygni.

"The Earth, like many planets and stars, has a magnetic field that sprouts out of the North Pole, circles the planet and goes back into the South Pole. It exists because the Earth has a hot, liquid iron rich core," said Packham. "That flow creates electric currents that create a magnetic field. A black hole has a magnetic field as it was created from the remnant of a star after the explosion."

As matter is broken down around a black hole, jets of electrons are launched by the magnetic field from either pole of the black hole at almost the speed of light. Astronomers have long been flummoxed by these jets.

These new and unique observations of the jets and estimates of magnetic field of V404 Cygni involved studying the body at several different wavelengths. These tests allowed the group to gain a much clearer understanding of the strength of its magnetic field. They discovered that magnetic fields are much weaker than previously understood, a puzzling finding that calls into question previous models of black hole components. The research shows a deep need for continued studies on some of the most mysterious entities in space.

"We need to understand black holes in general," Packham said. "If we go back to the very earliest point in our universe, just after the big bang, there seems to have always been a strong correlation between black holes and galaxies. It seems that the birth and evolution of black holes and galaxies, our cosmic island, are intimately linked. Our results are surprising and one that we're still trying to puzzle out." [20]

Black holes' magnetism surprisingly wimpy

Black holes are famous for their muscle: an intense gravitational pull known to gobble up entire stars and launch streams of matter into space at almost the speed of light.

It turns out the reality may not live up to the hype.

In a paper published today in the journal *Science*, University of Florida scientists have discovered these tears in the fabric of the universe have significantly weaker magnetic fields than previously thought.

A 40-mile-wide black hole 8,000 light years from Earth named V404 Cygni yielded the first precise measurements of the magnetic field that surrounds the deepest wells of gravity in the universe. Study authors found the magnetic energy around the black hole is about 400 times lower than previous crude estimates.

The measurements bring scientists closer to understanding how black holes' magnetism works, deepening our knowledge of how matter behaves under the most extreme conditions—knowledge that could broaden the limits of nuclear fusion power and GPS systems.

The measurements also will help scientists solve the half-century-old mystery of how "jets" of particles traveling at nearly the speed of light shoot out of black holes' magnetic fields, while everything else is sucked into their abysses, said study co-author Stephen Eikenberry, a professor of astronomy in UF's College of Liberal Arts and Sciences.

"The question is, how do you do that?" Eikenberry said. "Our surprisingly low measurements will force new constraints on theoretical models that previously focused on strong magnetic fields accelerating and directing the jet flows. We weren't expecting this, so it changes much of what we thought we knew."

Study authors developed the measurements from data collected in 2015 during a black hole's rare outburst of jets. The event was observed through the lens mirror of the 34-foot Gran Telescopio Canarias, the world's largest telescope, co-owned by UF and located in Spain's Canary Islands, with the help of its UF-built infrared camera named CIRCE (Canarias InfraRed Camera Experiment).

Smaller jet-producing black holes, like the one observed for the study, are the rock stars of galaxies. Their outbursts occur suddenly and are short-lived, said study lead author Yigit Dalilar and co-author Alan Garner, doctoral students in UF's astronomy department. The 2015 outbursts of V404 Cygni lasted only a couple of weeks. The previous time the same black hole had a similar episode was in 1989.

"To observe it was something that happens once or twice in one's career," Dalilar said. "This discovery puts us one step closer to understanding how the universe works." [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.

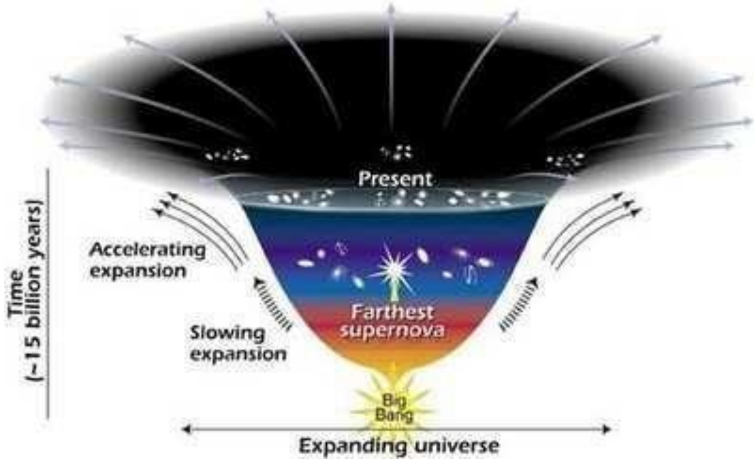
The scenario is plausible, says Raymond Volkas, a physicist at the University of Melbourne who was not involved in the study, but the missing pulsar problem might easily turn out to have a mundane explanation through known stellar effects. "It would, of course, be exciting to have dramatic direct astrophysical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

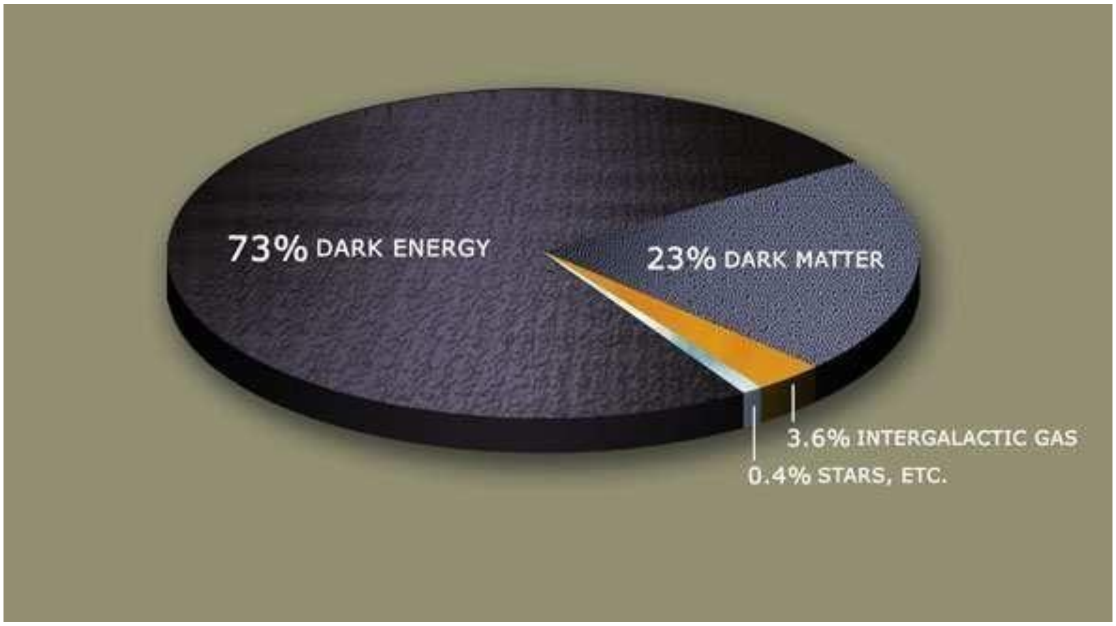
The accelerating expansion of the universe was discovered when astronomers were doing research on type 1a supernova events. These stellar explosions play a pivotal role in discerning the distance between two celestial objects because all type 1a supernova explosions are remarkably similar in brightness.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

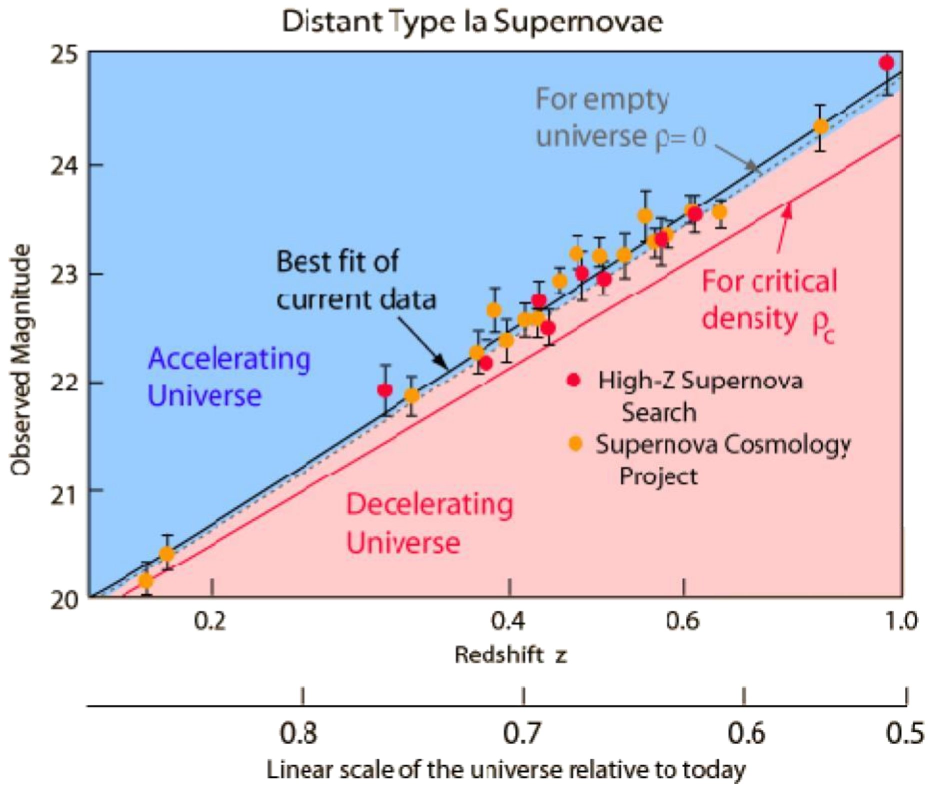
Cosmology underwent a paradigm shift in 1998 when researchers announced that the rate at which the Universe was expanding was accelerating. The idea of a constant dark energy throughout spacetime (the “cosmological constant”) became the standard model of cosmology, but now the Portsmouth and Rome researchers 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: $\Lambda = 8\pi\rho_{vac}$, where unit conventions of general relativity are used (otherwise factors of *G* and *c* would also appear). It is common to quote values of energy density directly, though still using the name "cosmological constant".

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

Explanatory models

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

Dark Matter and Energy

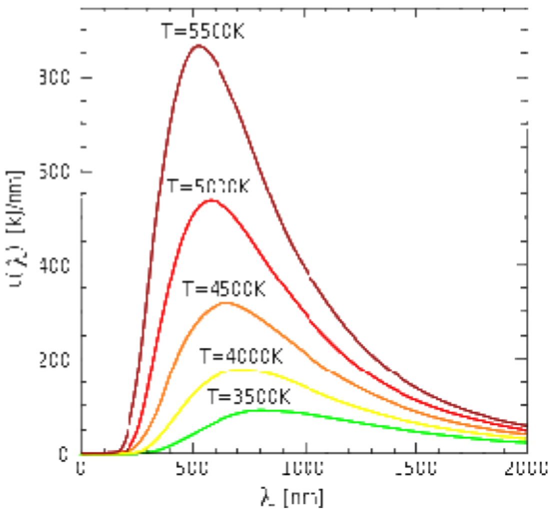
Dark matter is a type of matter hypothesized in astronomy and cosmology to account for a large part of the mass that appears to be missing from the universe. Dark matter cannot be seen directly with telescopes; evidently it neither emits nor absorbs light or other electromagnetic radiation at any significant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

Cosmic microwave background

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

Thermal radiation

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



Electromagnetic Field and Quantum Theory

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

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

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

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

Lorentz transformation of the Special Relativity

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

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

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

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

The Classical Relativistic effect

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

Electromagnetic inertia and Gravitational attraction

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

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

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

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

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

Electromagnetic inertia and mass

Electromagnetic Induction

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Relativistic change of mass

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The frequency dependence of mass

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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]

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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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