Gravitational Waves with Black Holes

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Astronomers on Wednesday unveiled the first photo of a black hole, one of the star-devouring monsters scattered throughout the Universe and obscured by impenetrable shields of gravity. [25]

Paul McNamara, an astrophysicist at the European Space Agency and project scientist for the LISA mission that will track massive black hole mergers from space, helped AFP put what he called an "outstanding technical achievement" into context. [24]

We're about to see the first close-up of a black hole. [23]

In short, the concept of a black hole gravity machine presents humanity with a plausible path to becoming an interstellar species. In the meantime, the study of the concept will provide SETI researchers with another possible technosignature to look for. [22]

Physicists have used a seven-qubit quantum computer to simulate the scrambling of information inside a black hole, heralding a future in which entangled quantum bits might be used to probe the mysterious interiors of these bizarre objects. [21]

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

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

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

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

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

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

A team of researchers from around the world is getting ready to create what might be the first image of a black hole. [14]

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

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

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

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

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

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

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Author: George Rajna

DIY gravitational waves with 'BlackHoles@Home'

Researchers hoping to better interpret data from the detection of gravitational waves generated by the collision of binary black holes are turning to the public for help.

West Virginia University assistant professor Zachariah Etienne is leading what will soon become a global volunteer computing effort. The public will be invited to lend their own computers to help the scientific community unlock the secrets contained in gravitational waves observed when black holes smash together.

LIGO's first detection of gravitational waves from colliding black holes in 2015 opened a new window on the universe, enabling scientists to observe cosmic events spanning billions of years and to better understand the makeup of the Universe. For many scientists, the discovery also fueled expansion of efforts to more thoroughly test the theories that help explain how the universe works—with a particular focus on inferring as much information as possible about the black holes prior to their collision.

First predicted by Albert Einstein in 1916, gravitational waves are ripples or disturbances in space-time that encode important information about changing gravitational fields.

Since the 2015 discovery, LIGO and Virgo have detected gravitational waves from eight additional black hole collisions. This month, LIGO and Virgo began new observing runs at unprecedented sensitivities.

"As our gravitational wave detectors become more sensitive, we're going to need to greatly expand our efforts to understand all of the information encoded in gravitational waves from colliding binary black holes," Etienne said. "We are turning to the general public to help with these efforts, which involve generating unprecedented numbers of self-consistent simulations of these extremely energetic collisions. This will truly be an inclusive effort, and we especially hope to inspire the next generation of scientists in this growing field of gravitational wave astrophysics."

His team—and the scientific community in general—needs computing capacity to run the simulations required to cover all possibilities related to the properties and other information contained in gravitational waves.

"Each desktop computer will be able to perform a single simulation of colliding black holes," said Etienne. By seeking public involvement through use of vast numbers of personal desktop computers, Etienne and others hope to dramatically increase the throughput of the theoretical gravitational wave predictions needed to extract information from observations of the collisions.

Black holes are known to contain two physical quantities: spin and mass. Spin, for example, can then be broken down further into direction and speed. Etienne's colleagues, therefore, are examining a total of eight parameters when LIGO or Virgo detect waves from a collision of two black holes.

"The simulations we need to perform, with the public's help, are designed to fill large gaps in our knowledge about gravitational waves from these collisions by covering as many possibilities as we can for these eight parameters. Current black hole simulation catalogs are far too small to properly cover this wide space of possibilities," Etienne said.

"This work aims to provide a critical service to the scientific community: an unprecedented large catalog of self-consistent theoretical predictions for what gravitational waves may be observed from black hole collisions. These predictions assume that Einstein's theory of gravity, general relativity, is correct, and therefore will provide deeper insights into this beautiful and complex theory. Just to give you an idea of its importance—if the effects of Einstein's relativity theory weren't accounted for, GPS systems would be off by kilometers per day, just to name one example."

Etienne and his team are building a website with downloadable software based on the same Berkeley Open Infrastructure for Network Computing, or BOINC, system used for the SETI@Home project and other scientific applications. The free middleware system is designed to help harness the processing power of thousands of personal computers across the globe. The West Virginia team has named their project BlackHoles@Home and expects to have it up and running later this year.

They have already established a website where the public can begin learning more about the effort: https://math.wvu.edu/~zetienne/SENR/. [26]

Astronomers deliver first photo of black hole

Astronomers on Wednesday unveiled the first photo of a black hole, one of the star-devouring monsters scattered throughout the Universe and obscured by impenetrable shields of gravity.

The image of a dark core encircled by a flame-orange halo of white-hot gas and plasma looks like any number of artists' renderings over the last 30 years.

But this time, it's the real deal.

Scientists have been puzzling over invisible "dark stars" since the 18th century, but never has one been spied by a telescope, much less photographed.

The supermassive black hole now immortalised by a far-flung network of radio telescopes is 50 million lightyears away in a galaxy known as M87.

"It's a distance that we could have barely imagined," Frederic Gueth, an astronomer at France's National Centre for Scientific Research (CNRS) and co-author of studies detailing the findings, told AFP.

Most speculation had centred on the other candidate targeted by the Event Horizon Telescope—Sagittarius A*, the black hole at the centre of our own galaxy, the Milky Way.

By comparison, Sag A* is only 26,000 lightyears from Earth.

Locking down an image of M87's supermassive black hole at such distance is comparable to photographing a pebble on the Moon.

European Space Agency astrophysicist Paul McNamara called it an "outstanding technical achievement".

It was also a team effort.

"Instead of constructing a giant telescope that would collapse under its own weight, we combined many observatories," Michael Bremer, an astronomer at the Institute for Millimetric Radio Astronomy (IRAM) in Grenoble, told AFP.

Earth in a thimble

Over several days in April 2017, eight radio telescopes in Hawaii, Arizona, Spain, Mexico, Chile, and the South Pole zeroed in on Sag A* and M87.

Knit together "like fragments of a giant mirror," in Bremer's words, they formed a virtual observatory some 12,000 kilometres across—roughly the diameter of Earth.

In the end, M87 was more photogenic. Like a fidgety child, Sag A* was too "active" to capture a clear picture, the researchers said.

"The telescope is not looking at the black hole per se, but the material it has captured," a luminous disk of white-hot gas and plasma known as an accretion disk, said McNamara, who was not part of the team.

"The light from behind the black hole gets bent like a lens."

The Event Horizon Telescope (EHT) -- a planet-scale array of eight ground-based radio telescopes forged through international collaboration -- was designed to capture images of a black hole. Today, in coordinated press conferences across the globe, EHT researchers reveal that they have succeeded, unveiling the first direct visual evidence of a supermassive black hole and its shadow.

For more multimedia, visit NSF.gov/blackhole, including text-free versions of all images. Credit: NSF

The unprecedented image—so often imagined in science and science fiction —- has been analysed in six studies co-authored by 200 experts from 60-odd institutions and published Wednesday in *Astrophysical Journal Letters*.

"I never thought that I would see a real one in my lifetime," said CNRS astrophysicist Jean-Pierre Luminet, author in 1979 of the first digital simulation of a black hole.

Coined in the mid-60s by American physicist John Archibald Wheeler, the term "black hole" refers to a point in space where matter is so compressed as to create a gravity field from which even light cannot escape.

The more mass, the bigger the hole.

At the same scale of compression, Earth would fit inside a thimble. The Sun would measure a mere six kilometres edge-to-edge.

A successful outcome depended in part on the vagaries of weather during the April 2017 observation period.

"For everything to work, we needed to have clear visibility at every [telescope] location worldwide", said IRAM scientist Pablo Torne, recalling collective tension, fatigue and, finally, relief.

'Hell of a Christmas present'

Torne was at the controls of the Pico Veleta telescope in Spain's Sierra Madre mountains.

The Event Horizon Telescope (EHT) -- a planet-scale array of eight ground-based radio telescopes forged through international collaboration -- was designed to capture images of a black hole. For more multimedia, visit NSF.gov/blackhole. Credit: NSF

After that, is was eight months of nail-biting while scientists at MIT Haystack Observatory in Massachusetts and the Max Planck Institute for Radio Astronomy in Bonn crunched the data.

The Universe is filled with electromagnetic "noise", and there was no guarantee M87's faint signals could be extracted from a mountain of data so voluminous it could not be delivered via the Internet.

There was at least one glitch.

"We were desperately waiting for the data from the South Pole Telescope, which—due to extreme weather conditions during the southern hemisphere winter—didn't arrive until six months later," recalled Helger Rottmann from the Max Planck Institute.

It arrived, to be precise, on December 23, 2017.

"When, a few hours later, we saw that everything was there, it was one hell of a Christmas present," Rottmann said.

It would take another year, however, to piece together the data into an image.

"To be absolutely sure, we did the work four times with four different teams," said Gueth.

Each team came up with exactly the same spectacular, history-making picture of a dark circle encased in a flaming-red halo. [25]

Black holes: picturing the heart of darkness

Astronomers are poised Wednesday to unveil the first direct image of a black hole and the surrounding whirlwind of white-hot gas and plasma inexorably drawn by gravity into its ravenous maw, along with the light they generate.

The picture will have been captured by the Event Horizon Telescope (EHT), a network of eight radio telescopes scattered across the globe.

Paul McNamara, an astrophysicist at the European Space Agency and project scientist for the LISA mission that will track massive black hole mergers from space, helped AFP put what he called an "outstanding technical achievement" into context.

How do we know black holes exist?

"We think, of course, of a black hole as something very dark. But the mass it sucks in forms a so-called accretion disk that gets so hot it glows and emits light.

Over the years, we accumulated other indirect observational evidence -— X-rays coming off objects, for example, in other galaxies.

In September 2015, the LIGO gravitational wave detectors in the US made a measurement of two black holes smashing together.

All the evidence we have from around the universe -— X-rays, radio-waves, light -— points to these very compact objects, and the gravitational waves confirmed that they really are black holes, even if we have never actually seen one."

What is an 'event horizon'?

"At the centre of a black hole is something we call a 'singularity' -— a huge amount of mass shrunk down to an infinitely small, zero-dimensional point in space.

If you get a certain distance away from that singularity, the escape velocity drops under the speed of light. That's the event horizon.

It is not a physical barrier -— you couldn't stand on it. If you're on the inside of it, you can't escape because you would need infinite energy. If you are on the other side, you could escape—in principle."

How big is a black hole?

"The diameter of a black hole depends on its mass but it is always double what we call the Schwarzschild radius.

If the Sun were to shrink to a singularity point, the Schwarzschild radius would be three kilometres, and the diameter would be six.

Supermassive black holes rip up and devour hapless stars a hundred times more frequently than thought, according to research released in 2017

For Earth, the diameter would be 18 millimetres, or about three-quarters of an inch. The event horizon of the black hole at the centre of the Milky Way, Sagittarius A*, measures about 24 million kilometres across.

Sagittarius A*—which has four million times the mass of the Sun—is one of two black holes targeted by the EHT. The other, even bigger, is in the galaxy M87."

What will the image look like?

"The Event Horizon Telescope is not looking at the black hole per se, but the material it has captured.

It won't be a big disk in high resolution like in the Hollywood movie 'Interstellar'. But we might see a black core with a bright ring—the accretion disk—around it.

The light from behind the black hole gets bent like a lens. No matter what the orientation of the disc, you will see it as a ring because of the black hole's strong gravity.

Visually, it will look very much like an eclipse, though the mechanism, of course, is completely different."

How is the image generated?

"The technical achievement is outstanding. Rather than having one telescope that is 100 metres across, they have lots of telescopes with an effective diameter of 12,000 kilometres—the diameter of Earth.

The data is recorded with very high accuracy, put onto hard disks, and shipped to a central location where the image is reconstructed digitally.

This is very, very, very long baseline interferometry -– over the entire surface of the Earth."

Any threat to general relativity?

"Einstein's theory of general relativity fits all the observations made so far related to black holes.

The gravitational wave signature from the LIGO experiments, for example, was exactly what the theory says would be expected.

But the black holes LIGO measured were small, only 60-100 times the mass of the Sun. Maybe black holes millions of times more massive are different. We don't know yet.

We should see a ring. If we see something elongated on one axis, then it can no longer be a singularity—that could be a violation of general relativity." [24]

4 things we'll learn from the first closeup image of a black hole

We're about to see the first close-up of a black hole.

The Event Horizon Telescope, a network of eight radio observatories spanning the globe, has set its sights on a pair of behemoths: Sagittarius A*, the supermassive black hole at the Milky Way's center, and an even more massive black hole 53.5 million light-years away in galaxy M87 (*SN Online: 4/5/17*).

In April 2017, the observatories teamed up to observe the black holes' event horizons, the boundary beyond which gravity is so extreme that even light can't escape (*SN: 5/31/14, p. 16*). After almost two years of rendering the data, scientists are gearing up to release the first images in April.

Here's what scientists hope those images can tell us.

What does a black hole really look like?

Black holes live up to their names: The great gravitational beasts emit no light in any part of the electromagnetic spectrum, so they themselves don't look like much.

But astronomers know the objects are there because of a black hole's entourage. As a black hole's gravity pulls in gas and dust, matter settles into an orbiting disk, with atoms jostling one another at extreme speeds. All that activity heats the matter white-hot, so it emits X-rays and other high-energy radiation. The most voraciously feeding black holes in the universe have disks that outshine all the stars in their galaxies (*SN Online: 3/16/18*).

A CAMERA THE SIZE OF EARTH How did scientists take a picture of a black hole? *Science News* explains.

The EHT's image of the Milky Way's Sagittarius A*, also called SgrA*, is expected to capture the black hole's shadow on its accompanying disk of bright material. Computer simulations and the laws of gravitational physics give astronomers a pretty good idea of what to expect. Because of the intense gravity near a black hole, the disk's light will be warped around the event horizon in a ring, so even the material behind the black hole will be visible.

And the image will probably look asymmetrical: Gravity will bend light from the inner part of the disk toward Earth more strongly than the outer part, making one side appear brighter in a lopsided ring.

Does general relativity hold up close to a black hole?

The exact shape of the ring may help break one of the most frustrating stalemates in theoretical physics.

The twin pillars of physics are Einstein's theory of general relativity, which governs massive and gravitationally rich things like black holes, and quantum mechanics, which governs the weird world of subatomic particles. Each works precisely in its own domain. But they can't work together.

"General relativity as it is and quantum mechanics as it is are incompatible with each other," says physicist Lia Medeiros of the University of Arizona in Tucson. "Rock, hard place. Something has to give." If general relativity buckles at a black hole's boundary, it may point the way forward for theorists.

Since black holes are the most extreme gravitational environments in the universe, they're the best environment to crash test theories of gravity. It's like throwing theories at a wall and seeing whether — or how — they break. If general relativity does hold up, scientists expect that the black hole will have a particular shadow and thus ring shape; if Einstein's theory of gravity breaks down, a different shadow.

Medeiros and her colleagues ran computer simulations of 12,000 different black hole shadows that could differ from Einstein's predictions. "If it's anything different, [alternative theories of gravity] just got a Christmas present," says Medeiros, who presented the simulation results in January in Seattle at the American Astronomical Society meeting. Even slight deviations from general relativity could create different enough shadows for EHT to probe, allowing astronomers to quantify how different what they see is from what they expect.

CONSIDERING ALL POSSIBILITIES Physicists expect black holes to follow Einstein's rules of general relativity, but it might be more interesting if they don't. This computer simulation shows one possibility for how a black hole would look if it behaved unexpectedly.

Do stellar corpses called pulsars surround the Milky Way's black hole?

Another way to test general relativity around black holes is to watch how stars careen around them. As light flees the extreme gravity in a black hole's vicinity, its waves get stretched out, making the light appear redder. This process, called gravitational redshift, is predicted by general relativity and was observed near SgrA* last year (*SN: 8/18/18, p. 12*). So far, so good for Einstein.

An even better way to do the same test would be with a pulsar, a rapidly spinning stellar corpse that sweeps the sky with a beam of radiation in a regular cadence that makes it appear to pulse (*SN: 3/17/18, p. 4*). Gravitational redshift would mess up the pulsars' metronomic pacing, potentially giving a far more precise test of general relativity.

"The dream for most people who are trying to do SgrA* science, in general, is to try to find a pulsar or pulsars orbiting" the black hole, says astronomer Scott Ransom of the National Radio Astronomy Observatory in Charlottesville, Va. "There are a lot of quite interesting and quite deep tests of [general relativity] that pulsars can provide, that EHT [alone] won't."

Despite careful searches, no pulsars have been found near enough to SgrA* yet, partly because gas and dust in the galactic center scatters their beams and makes them difficult to spot. But EHT is taking the best look yet at that center in radio wavelengths, so Ransom and colleagues hope it might be able to spot some.

"It's a fishing expedition, and the chances of catching a whopper are really small," Ransom says. "But if we do, it's totally worth it."

ONE OF MANY? The pulsar PSR J1745-2900 (left in this illustration) was discovered in 2013 orbiting roughly 150 light-years from the black hole at the center of the galaxy. That's too far to use it to do precise tests of general relativity, but astronomers hope that the pulsar's existence means the Event Horizon Telescope will find many more even closer to the black hole.

RALPH EATOUGH/MPIFR

How do some black holes make jets?

Some black holes are ravenous gluttons, pulling in massive amounts of gas and dust, while others are picky eaters. No one knows why. SgrA* seems to be one of the fussy ones, with a surprisingly dim accretion disk despite its 4 million solar mass heft. EHT's other target, the black hole in galaxy M87, is a voracious eater, weighing in at about 2.4 trillion solar masses. And it doesn't just amass a bright accretion disk. It also launches a bright, fast jet of charged subatomic particles that stretches for about 5,000 light-years.

"It's a little bit counterintuitive to think a black hole spills out something," says astrophysicist Thomas Krichbaum of the Max Planck Institute for Radio Astronomy in Bonn, Germany. "Usually people think it only swallows something."

Many other black holes produce jets that are longer and wider than entire galaxies and can extend billions of light-years from the black hole. "The natural question arises: What is so powerful to launch these jets to such large distances?" Krichbaum says. "Now with the EHT, we can for the first time trace what is happening."

EHT's measurements of M87's black hole will help estimate the strength of its magnetic field, which astronomers think is related to the jet-launching mechanism. And measurements of the jet's properties when it's close to the black hole will help determine where the jet originates — in the innermost part of the accretion disk, farther out in the disk or from the black hole itself. Those observations might also reveal whether the jet is launched by something about the black hole itself or by the fast-flowing material in the accretion disk.

Since jets can carry material out of the galactic center and into the regions between galaxies, they can influence how galaxies grow and evolve, and even where stars and planets form (*SN: 7/21/18, p. 16*).

"It is important to understanding the evolution of galaxies, from the early formation of black holes to the formation of stars and later to the formation of life," Krichbaum says. "This is a big, big story. We are just contributing with our studies of black hole jets a little bit to the bigger puzzle." [23]

Using black holes to conquer space: The halo drive

The idea of traveling to another star system has been the dream of people long before the first rockets and astronauts were sent to space. But despite all the progress we have made since the beginning of the Space Age, interstellar travel remains just that – a dream. While theoretical concepts have been proposed, the issues of cost, travel time and fuel remain highly problematic.

A lot of hopes currently hinge on the use of directed energy and lightsails to push tiny spacecraft to relativistic speeds. But what if there was a way to make larger spacecraft fast enough to conduct interstellar voyages? According to Prof. David Kipping, the leader of Columbia University's Cool

Worlds lab, future spacecraft could rely on a halo drive, which uses the gravitational force of a black hole to reach incredible speeds.

Prof. Kipping described this concept in a recent study that appeared online (the preprint is also available on the Cool Worlds website). In it, Kipping addressed one of the greatest challenges posed by space exploration, which is the sheer amount of time and energy it would take to send a spacecraft on a mission to explore beyond our solar system.

Kipping told Universe Today via email: "Interstellar travel is one of the most challenging technical feats we can conceive of. Whilst we can envisage drifting between the stars over millions of years – which is legitimately interstellar travel – to achieve journeys on timescales of centuries or less requires relativistic propulsion."

As Kipping put it, relativistic propulsion (or accelerating to a fraction of the speed of light) is very expensive in terms of energy. Existing spacecraft simply don't have the fuel capacity to get up to those kinds of speeds, and short of detonating nukes to generate thrust à la Project Orion, or building a fusion ramjet à la Project Daedalus, there are not a lot of options available.

In recent years, attention has shifted toward the idea of using lightsails and nanocraft to conduct interstellar missions. A well-known example is Breakthrough Starshot, an initiative that aims to send a smartphone-sized spacecraft to Alpha Centauri within our lifetime. Using a powerful laser array, the lightsail would be accelerated to speeds of up to 20 percent of the speed of light – thus making the trip in 20 years.

"But even here, you are talking about several terra-joules of energy for the most minimalist (a gram-mass) spacecraft conceivable," said Kipping. "That's the cumulative energy output of nuclear power stations running for weeks on end... so this is why it's hard."

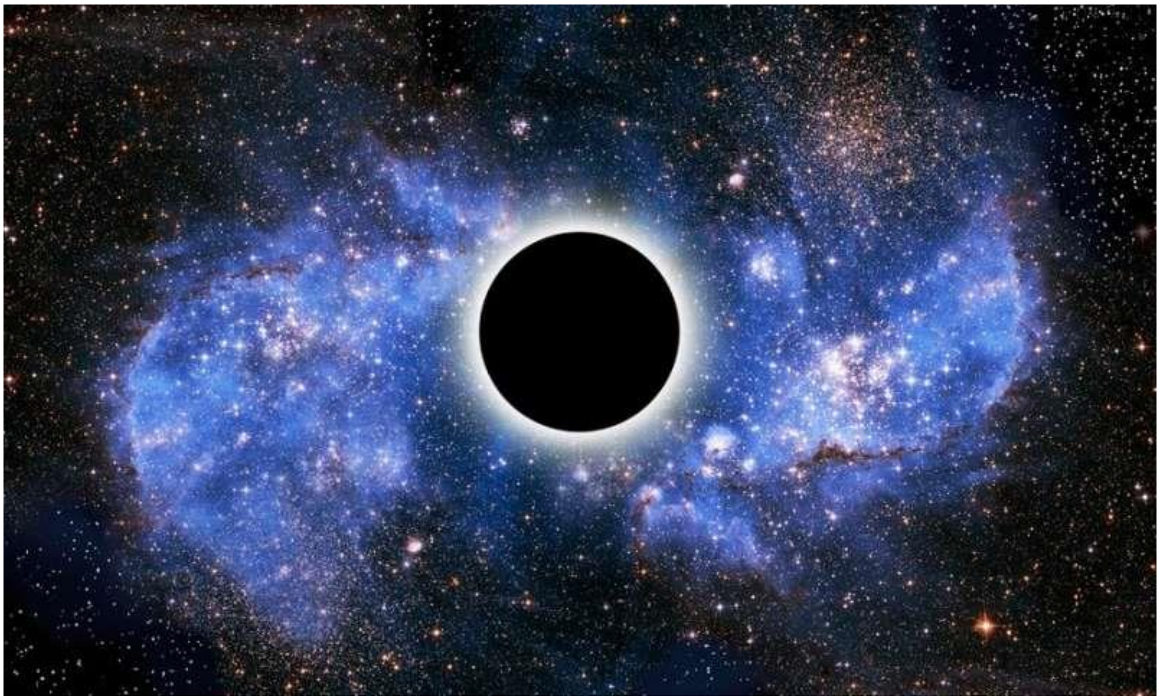
To this, Kipping suggests a modified version of the "Dyson Slingshot," an idea proposed by venerated theoretical physicist Freeman Dyson, the theorist behind the Dyson Sphere. In the 1963 book *Interstellar Communications* (Chapter 12: "Gravitational Machines"), Dyson described how spacecraft could slingshot around compact binary stars in order to receive a significant boost in velocity.

As Dyson described it, a ship would be dispatched to a compact binary system where it would perform a gravity-assist maneuver. This would consist of the spaceship picking up speed from the binary's intense gravity, adding the equivalent of twice their rotational velocity to its own, and is then flung out of the system.

While the prospect of harnessing this kind of energy for the sake of propulsion was highly theoretical in Dyson's time (and still is), Dyson offered two reasons why "gravitational machines" were worth exploring:

"First, if our species continues to expand its population and its technology at an exponential rate, there may come a time in the remote future where engineering on an astronomical scale may be both feasible and necessary. Second, if we are searching for signs of technologically advanced life already existing elsewhere in the universe, it is useful to consider what kind of observable phenomena a really advanced technology might be capable of producing."

In short, gravitational machines are worth studying in case they become possible someday, and because this study could allow us to spot possible extraterrestrial intelligences (ETIs) by detecting the technosignatures such machines would create. Expanding upon this, Kipping considers how black holes, especially those found in binary pairs, could constitute even more powerful gravitational slingshots.



Artist's conception of the event horizon of a black hole. Credit: Victor de Schwanberg/Science Photo Library

This proposal is based in part on the recent success of the Laser Interferometer Gravitational-Wave Observatory (LIGO), which has detected multiple gravitational wave signals since 2016. According to recent estimates based on these detections, there could be as many as 100 million black holes in the Milky Way galaxy alone.

Where binaries occur, they possess an incredible amount of rotational energy, which is the result of their spin and the way they rapidly orbit one another. In addition, as Kipping notes, black holes can also act as a gravitational mirror – where photons directed at the edge of the event horizon will bend around and come straight back at the source. As Kipping put it:

"So the binary black hole is really a couple of giant mirrors circling around one another at potentially high velocity. The halo drive exploits this by bouncing photons off the "mirror" as the mirror approaches you, the photons bounce back, pushing you along, but also steal some of the energy from the black hole binary itself (think about how a ping pong ball thrown against a moving wall would come back faster). Using this setup, one can harvest the binary black hole energy for propulsion."

This method of propulsion offers several obvious advantages. For starters, it offers users the potential to travel at relativistic speeds without the need for fuel, which currently accounts for the majority of a launch vehicle's mass. And there are many, many black holes that exist throughout the Milky Way, which could act as a network for relativistic space travel.

What's more, scientists have already witnessed the power of gravitational slingshots thanks to the discovery of hyper-velocity stars. According to research from the Harvard-Smithsonian Center for Astrophysics (CfA), these stars are a result of galactic mergers and interaction with massive black holes, which kick them out of their galaxies at one-tenth to one-third the speed of light – around 30,000 to 100,000 km/s (18,600 to 62,000 mps).

But of course, the concept comes with innumerable challenges and more than a few disadvantages. In addition to building spacecraft that can endure being flung around the event horizon of a black hole, a tremendous amount of precision is required – otherwise, the ship and crew (if it has one) could be pulled apart in the maw of the black hole. Additionally, there's simply the matter of reaching one:

"[T]he thing has a huge disadvantage for us in that we have to first get to one of these black holes. I tend to think of it like a interstellar highway system – you have to pay a one-time toll to get on the highway, but once you're on, you can ride across the galaxy as much as you like without expending any more fuel."

The challenge of how humanity might go about reaching the nearest suitable black hole will be the subject of Kipping's next paper, he indicated. And while an idea like this is about as remote to us as building a Dyson Sphere or using black holes to power starships, it does offer some pretty exciting possibilities for the future.

In short, the concept of a black hole gravity machine presents humanity with a plausible path to becoming an interstellar species. In the meantime, the study of the concept will provide SETI researchers with another possible technosignature to look for. So until the day comes when we might attempt this ourselves, we will be able to see if any other species have already made it work. [22]

Can entangled qubits be used to probe black holes?

Physicists have used a seven-qubit quantum computer to simulate the scrambling of information inside a black hole, heralding a future in which entangled quantum bits might be used to probe the mysterious interiors of these bizarre objects.

Scrambling is what happens when matter disappears inside a black hole. The information attached to that matter—the identities of all its constituents, down to the energy and momentum of its most elementary particles—is chaotically mixed with all the other matter and information inside, seemingly making it impossible to retrieve.

This leads to a so-called "black hole information paradox," since quantum mechanics says that information is never lost, even when that information disappears inside a black hole.

So, while some physicists claim that information falling through the event horizon of a black hole is lost forever, others argue that this information can be reconstructed, but only after waiting an inordinate amount of time—until the black hole has shrunk to nearly half its original size. Black holes shrink because they emit Hawking radiation, which is caused by quantum mechanical fluctuations at the very edge of the black hole and is named after the late physicist Stephen Hawking.

Unfortunately, a black hole the mass of our sun would take about 10^{67} years to evaporate—far, far longer than the age of the universe.

However, there is a loophole—or rather, a wormhole—out of this black hole. It may be possible to retrieve this infalling information significantly faster by measuring subtle entanglements between the black hole and the Hawking radiation it emits.

Two bits of information—like the quantum bits, or qubits, in a quantum computer—are entangled when they are so closely linked that the quantum state of one automatically determines the state of the other, no matter how far apart they are. Physicists sometimes refer to this as "spooky action at a distance," and measurements of entangled qubits can lead to the "teleportation" of quantum information from one qubit to another.

"One can recover the information dropped into the black hole by doing a massive quantum calculation on these outgoing Hawking photons," said Norman Yao, a UC Berkeley assistant professor of physics. "This is expected to be really, really hard, but if quantum mechanics is to be believed, it should, in principle, be possible. That's exactly what we are doing here, but for a tiny three-qubit `black hole' inside a seven-qubit quantum computer."

By dropping an entangled qubit into a black hole and querying the emerging Hawking radiation, you could theoretically determine the state of a qubit inside the black hole, providing a window into the abyss.

Yao and his colleagues at the University of Maryland and the Perimeter Institute for Theoretical Physics in Waterloo, Ontario, Canada, will report their results in a paper appearing in the March 6 issue of the journal *Nature*.

Scientists have implemented a test for quantum scrambling, which is a chaotic shuffling of the information stored among a collection of quantum particles. Quantum scrambling is one suggestion for how information can fall into a black hole …more

Teleportation

Yao, who is interested in understanding the nature of quantum chaos, learned from friend and colleague Beni Yoshida, a theorist at the Perimeter Institute, that recovering quantum information falling into a black hole is possible if the information is scrambled rapidly inside the black hole. The more thoroughly it is mixed throughout the black hole, the more reliably the information can be retrieved via teleportation. Based on this insight, Yoshida and Yao proposed last year an experiment to provably demonstrate scrambling on a quantum computer.

"With our protocol, if you measure a teleportation fidelity that is high enough, then you can guarantee that scrambling happened within the quantum circuit," Yao said. "So, then we called up my buddy, Chris Monroe."

Monroe, a physicist at the University of Maryland in College Park who heads one of the world's leading trapped-ion quantum information groups, decided to give it a try. His group implemented the protocol proposed by Yoshida and Yao and effectively measured an out-of-time-ordered correlation function.

Called OTOCs, these peculiar correlation functions are created by comparing two quantum states that differ in the timing of when certain kicks or perturbations are applied. The key is being able to evolve a quantum state both forward and backward in time to understand the effect of that second kick on the first kick.

Monroe's group created a scrambling quantum circuit on three qubits within a seven-qubit trapped-ion quantum computer and characterized the resulting decay of the OTOC. While the decay of the OTOC is typically taken as a strong indication that scrambling has occurred, to prove that they had to show that the OTOC didn't simply decay because of decoherence—that is, that it wasn't just poorly shielded from the noise of the outside world, which also causes quantum states to fall apart.

Yao and Yoshida proved that the greater the accuracy with which they could retrieve the entangled or teleported information, the more stringently they could put a lower limit on the amount of scrambling that had occurred in the OTOC.

Monroe and his colleagues measured a teleportation fidelity of approximately 80 percent, meaning that perhaps half of the quantum state was scrambled and the other half decayed by decoherence. Nevertheless, this was enough to demonstrate that genuine scrambling had indeed occurred in this three-qubit quantum circuit.

"One possible application for our protocol is related to the benchmarking of quantum computers, where one might be able to use this technique to diagnose more complicated forms of noise and decoherence in quantum processors," Yao said.

Yao is also working with a UC Berkeley group led by Irfan Siddiqi to demonstrate scrambling in a different quantum system, superconducting qutrits: quantum bits that have three, rather than two, states. Siddiqi, a UC Berkeley professor of physics, also leads the effort at Lawrence Berkeley National Laboratory to build an advanced quantum computing test bed.

"At its core, this is a qubit or qutrit experiment, but the fact that we can relate it to cosmology is because we believe the dynamics of quantum information is the same," he said. "The U.S. is launching a billion-dollar quantum initiative, and understanding the dynamics of quantum information connects many areas of research within this initiative: quantum circuits and computing, high energy physics, black hole dynamics, condensed matter physics and atomic, molecular and optical physics. The language of quantum information has become pervasive for our understanding of all these different systems."

Aside from Yao, Yoshida and Monroe, other co-authors are UC Berkeley graduate student T. Schuster and K. A. Landsman, C. Figgatt and N. M. Linke of Maryland's Joint Quantum Institute. The work was supported by the Department of Energy and the National Science Foundation. [21]

Black holes, curved spacetime and quantum computing

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

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

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

The photons that make up the X-rays have two properties: polarisation and orbital angular momentum. Each of these can encode a qubit (quantum bit) of information, the standard information unit in quantum computing. "Lab-based researchers already use beam splitters and prisms to entangle these properties in X-ray photons and process quantum information," says Racorean. "It now seems that the curvature of spacetime around a black hole will play the same role as this apparatus."

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

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

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

Some black holes erase your past

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

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

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

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

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

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

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

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

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

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

Beyond the event horizon

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

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

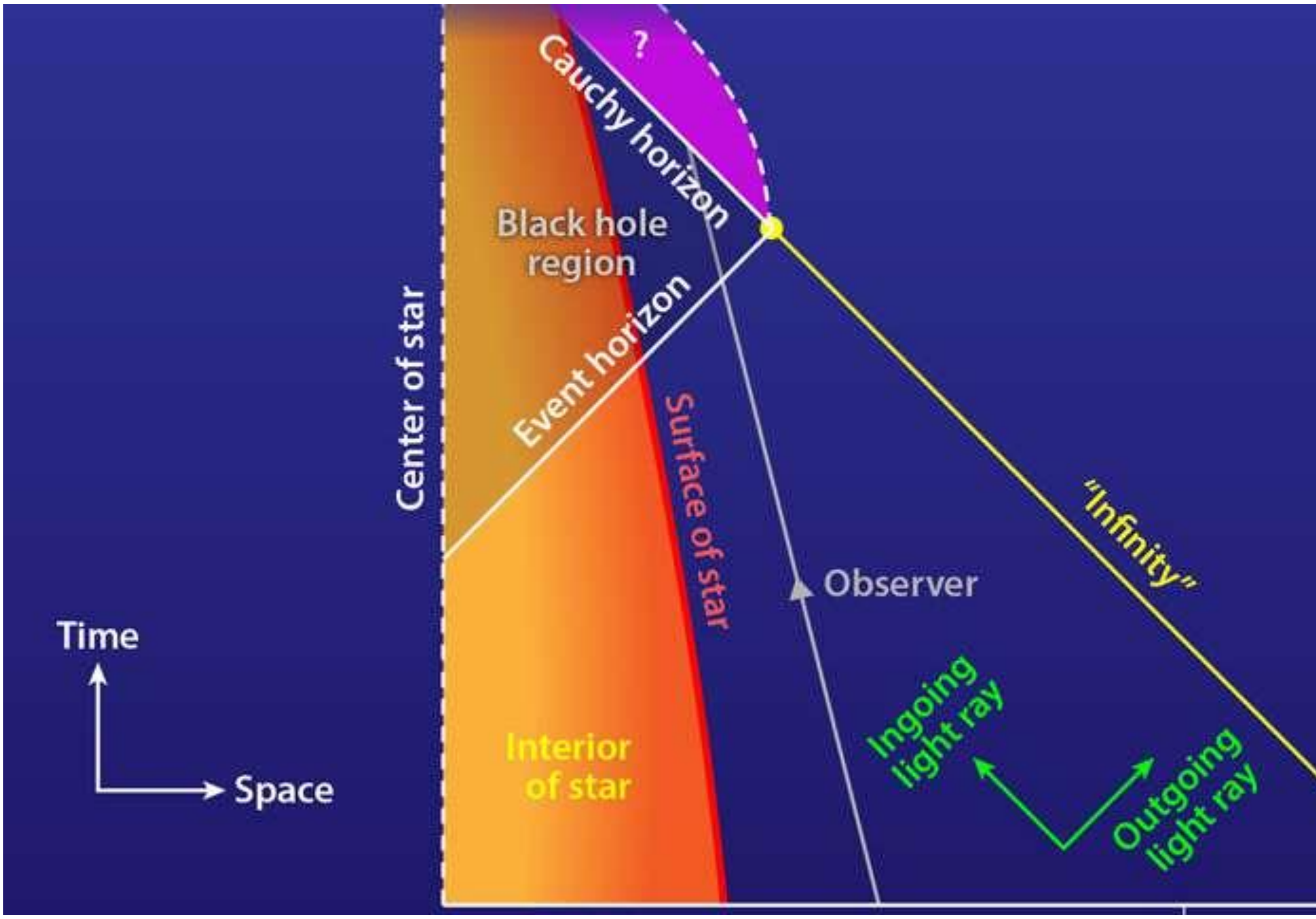
But for large black holes, like the supermassive objects at the cores of galaxies like the Milky Way, which weigh tens of millions if not billions of times the mass of a star, crossing the event horizon would be, well, uneventful.

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

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

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

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



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

You can't see forever in an expanding universe

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Spinning Black Holes Could Create Clouds of Mass

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

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

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

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

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

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

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

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

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

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

Mapping super massive black holes in the distant universe

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

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

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

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

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

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

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

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

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

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

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

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

Astronomers hoping to directly capture image of a black hole

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

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

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

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

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

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

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

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

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

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

Scientists readying to create first image of a black hole

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The universe appears to be teeming with invisible dark matter, which can neither be seen nor touched, but nonetheless exerts a gravitational pull on regular matter.
Scientists have several ideas for what dark matter might be made of, but none have been proved. A leading option suggests that dark matter is composed of particles called weakly interacting massive particles (WIMPs), which are traditionally thought to be both matter and antimatter in one. The nature of antimatter is important for the story. When matter and antimatter meet they destroy one another in powerful explosions—so when two regular WIMPs collide, they would annihilate one another.

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

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

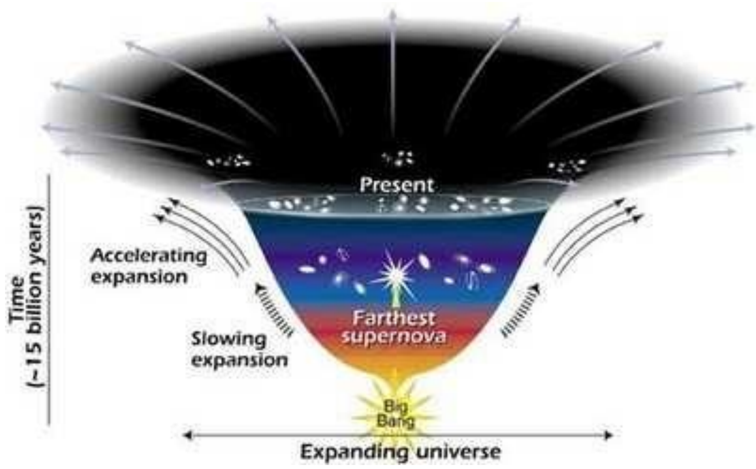
The scenario is plausible, says Raymond Volkas, a physicist at the University of Melbourne who was not involved in the study, but the missing pulsar problem might easily turn out to have a mundane explanation through known stellar effects. "It would, of course, be exciting to have dramatic direct astrophysical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

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

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

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

Everything You Need to Know About Dark Energy



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

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

How We Discovered That The Universe Is Expanding:

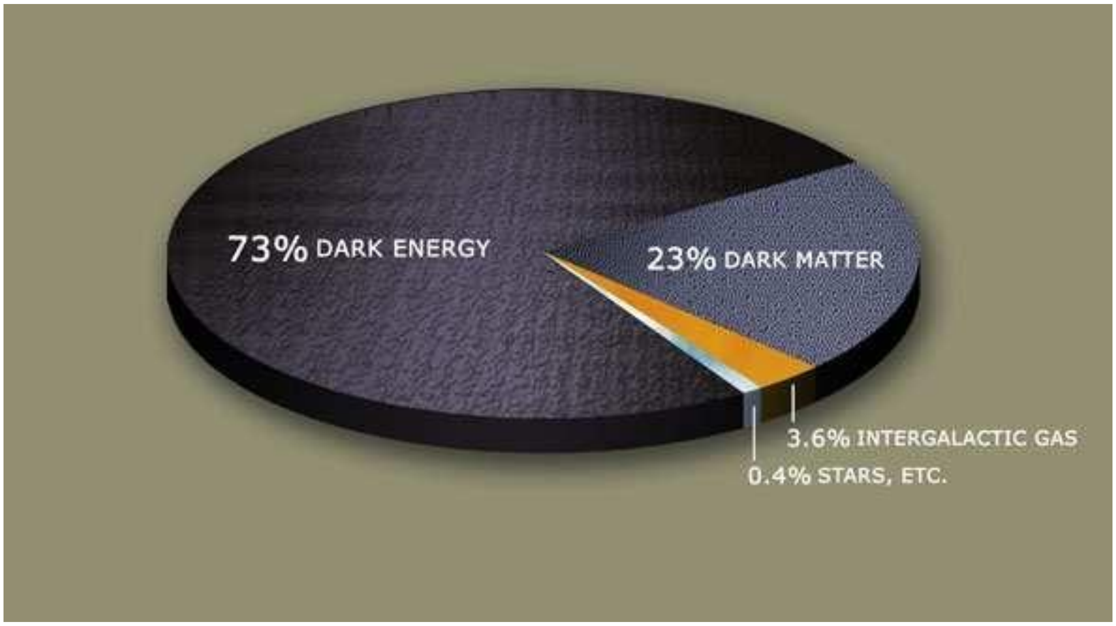
The accelerating expansion of the universe was discovered when astronomers were doing research on type 1a supernova events. These stellar explosions play a pivotal role in discerning the distance between two celestial objects because all type 1a supernova explosions are remarkably similar in brightness. So if we know how bright a star should be, we can compare the apparent luminosity with the intrinsic luminosity, and we get a reliable figure for how far any given object is from us. To get a better idea of how these work, think about headlights. For the most part, car headlights all have the same luminosity. So if one car's headlights are only 1/4 as bright as another car's, then one car is twice as far away as the other.

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

How Do We Know That Dark Energy Is Real?

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

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



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

How Does Dark Energy Work?

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

The Problem With Dark Energy:

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

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

The Significance:

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

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

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

The Big Bang

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

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

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

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

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

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

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

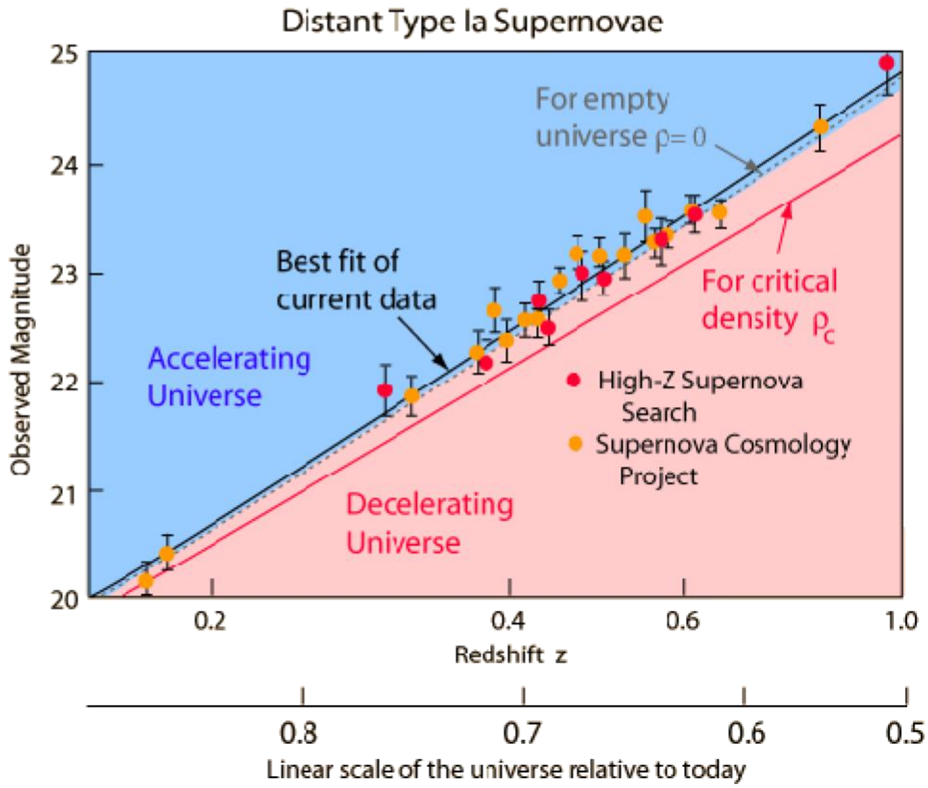
Cosmology underwent a paradigm shift in 1998 when researchers announced that the rate at which the Universe was expanding was accelerating. The idea of a constant dark energy throughout spacetime (the “cosmological constant”) became the standard model of cosmology, but now the Portsmouth and Rome researchers believe they have found a better description, including energy transfer between dark energy and dark matter. [10]

Evidence for an accelerating universe

One of the observational foundations for the big bang model of cosmology was the observed expansion of the universe. [9] Measurement of the expansion rate is a critical part of the study, and it has been found that the expansion rate is very nearly "flat". That is, the universe is very close to the critical density, above which it would slow down and collapse inward toward a future "big

crunch". One of the great challenges of astronomy and astrophysics is distance measurement over the vast distances of the universe. Since the 1990s it has become apparent that type Ia supernovae offer a unique opportunity for the consistent measurement of distance out to perhaps 1000 Mpc. Measurement at these great distances provided the first data to suggest that the expansion rate of the universe is actually accelerating. That acceleration implies an energy density that acts in opposition to gravity which would cause the expansion to accelerate. This is an energy density which we have not directly detected observationally and it has been given the name "dark energy".

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



The data summarized in the illustration above involve the measurement of the redshifts of the distant supernovae. The observed magnitudes are plotted against the redshift parameter z. Note that there are a number of Type 1a supernovae around z=.6, which with a Hubble constant of 71 km/s/mpc is a distance of about 5 billion light years.

Equation

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

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

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

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

The cosmological constant has the same effect as an intrinsic energy density of the vacuum, ρ_{vac} (and an associated pressure). In this context it is commonly moved onto the right-hand side of the equation, and defined with a proportionality factor of 8π: $\Lambda = 8\pi\rho_{vac}$, 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

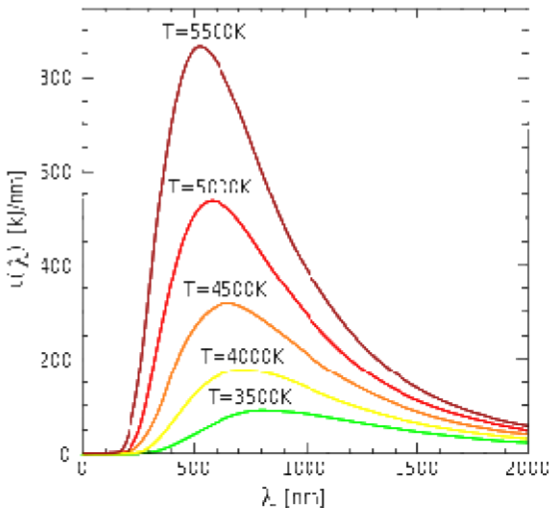
Dark matter is a type of matter hypothesized in astronomy and cosmology to account for a large part of the mass that appears to be missing from the universe. Dark matter cannot be seen directly with telescopes; evidently it neither emits nor absorbs light or other electromagnetic radiation at any significant 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 $E = h\nu$ and $E = mc^2$, $m = h\nu / c^2$ that is the m depends only on the ν frequency. It means that the mass of the proton and electron are electromagnetic and the result of the electromagnetic induction, caused by the changing acceleration of the spinning and moving charge! It could be that the m_o inertial mass is the result of the spin, since this is the only accelerating motion of the electric charge. Since the accelerating motion has different frequency for the electron in the atom and the proton, they masses are different, also as the wavelengths on both sides of the diffraction pattern, giving equal intensity of radiation.

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

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

Electromagnetic inertia and mass

Electromagnetic Induction

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

Relativistic change of mass

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The frequency dependence of mass

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Electron – Proton mass rate

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

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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.

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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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