South Downs Mercury

The monthly circular of South Downs Astronomical Society
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Main Talk Mike Foulkes Director of BAA Saturn Section via Zoom at the planetarium. "Saturn" Saturn is one of the most famous objects in the sky due to its system of rings. This talk gives an overview of this planet, ranging from an historical perspective up to present day knowledge. In particular, the talk describes the planet's rings and also some of the storms that have appeared in its atmosphere. It is illustrated with observations taken by spacecraft and by amateurs

Please support a raffle we are organizing this month

❖ NASA's Spitzer, TESS find potentially volcano-covered Earth-size world

Date: May 17, 2023
Source: NASA/Goddard Space Flight Centre

LP 791-18 d, shown here in an artist's concept, is an Earth-size world about 90 light-years away. The gravitational tug from a more massive planet in the system, shown as a blue disk in the background, may result in internal heating and volcanic eruptions – as much as Jupiter's moon Io, the most geologically active body in the solar system. Astronomers discovered and studied the planet using data from NASA's Spitzer Space Telescope and TESS (Transiting Exoplanet Survey Satellite) along with many other observatories. Credits: NASA's Goddard Space Flight Centre/Chris Smith (KRBwyle).

Astronomers have discovered an Earth-size exoplanet, or world beyond our solar system, that may be carpeted with volcanoes. Called LP 791-18 d, the planet could undergo volcanic outbursts as often as Jupiter's moon Io, the most volcanically active body in our solar system.

They found and studied the planet using data from NASA's TESS (Transiting Exoplanet Survey Satellite) and retired Spitzer Space Telescope, as well as a suite of ground-based observatories.

A paper about the planet -- led by Merrin Peterson, a graduate of the Trottier Institute for Research on Exoplanets (iREx) based at the University of Montreal -- appears in the May 17 edition of the scientific journal *Nature*.

"LP 791-18 d is tidally locked, which means the same side constantly faces its star," said Björn Benneke, a co-author and astronomy professor at iREx who planned and supervised the study. "The day side would probably be too hot for liquid water to exist on the surface. But the amount of volcanic activity we suspect occurs all over the planet could sustain an atmosphere, which may allow water to condense on the night side."

LP 791-18 d orbits a small red dwarf star about 90 light-years away in the southern constellation Crater. The team estimates it's only slightly larger and more massive than Earth.

Astronomers already knew about two other worlds in the system before this discovery, called LP 791-18 b and c. The inner planet b is about 20% bigger than Earth. The outer planet c is about 2.5 times Earth's size and more than seven times its mass.

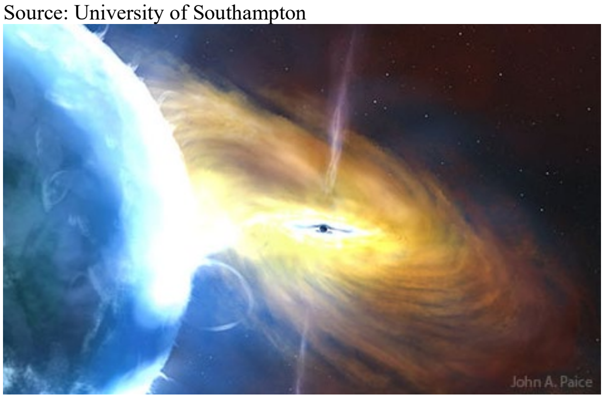
During each orbit, planets d and c pass very close to each other. Each close pass by the more massive planet c produces a gravitational tug on planet d, making its orbit somewhat elliptical. On this elliptical path, planet d is slightly deformed every time it goes around the star. These deformations can create enough internal friction to substantially heat the planet's interior and produce volcanic activity at its surface. Jupiter and some of its moons affect Io in a similar way.

Planet d sits on the inner edge of the habitable zone, the traditional range of distances from a star where scientists hypothesize liquid water could exist on a planet's surface. If the planet is as geologically active as the research team suspects, it could maintain an atmosphere. Temperatures could drop enough on the

planet's night side for water to condense on the surface.
Planet c has already been approved for observing time on the James Webb Space Telescope, and the team thinks planet d is also an exceptional candidate for atmospheric studies by the mission.
"A big question in astrobiology, the field that broadly studies the origins of life on Earth and beyond, is if tectonic or volcanic activity is necessary for life," said co-author Jessie Christiansen, a research scientist at NASA's Exoplanet Science Institute at the California Institute of Technology in Pasadena. "In addition to potentially providing an atmosphere, these processes could churn up materials that would otherwise sink down and get trapped in the crust, including those we think are important for life, like carbon."
Spitzer's observations of the system were among the last the satellite collected before it was decommissioned in January 2020.
"It is incredible to read about the continuation of discoveries and publications years beyond Spitzer's end of mission," said Joseph Hunt, Spitzer project manager at NASA's Jet Propulsion Laboratory in Southern California. "That really shows the success of our first-class engineers and scientists. Together they built not only a spacecraft but also a data set that continues to be an asset for the astrophysics community."
TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA's Goddard Space Flight Centre. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA's Ames Research Centre in California's Silicon Valley; the Centre for Astrophysics | Harvard & Smithsonian in Cambridge, Massachusetts; MIT's Lincoln Laboratory; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes, and observatories worldwide are participants in the mission.
The entire body of scientific data collected by Spitzer during its lifetime is available to the public via the Spitzer data archive, housed at the Infrared Science Archive at IPAC at Caltech in Pasadena, California. NASA's Jet Propulsion Laboratory, a division of Caltech, managed Spitzer mission operations for the agency's Science Mission Directorate in Washington. Science operations were conducted at the Spitzer Science Centre at IPAC at Caltech. Spacecraft operations were based at Lockheed Martin Space in Littleton, Colorado.

- Astronomers reveal the largest cosmic explosion ever seen

Date: May 12, 2023
Source: University of Southampton



Artist impression of a black hole accretion. Credit John A. Paice

A team of astronomers led by the University of Southampton have uncovered the largest cosmic explosion ever witnessed.
The explosion is more than ten times brighter than any known supernova (exploding star) and three times brighter than the brightest tidal disruption event, where a star falls into a supermassive black hole.
The explosion, known as AT2021lwx, has currently lasted over three years, compared to most supernovae which are only visibly bright for a few months. It took place nearly 8 billion light years away, when the universe was around 6 billion years old, and is still being detected by a network of telescopes.
The researchers believe that the explosion is a result of a vast cloud of gas, possibly thousands of times larger than our sun, that has been violently disrupted by a supermassive black hole. Fragments of the cloud would be swallowed up, sending shockwaves through its remnants, as well as into a large dusty 'doughnut' surrounding the black hole. Such events are very rare and nothing on this scale has been witnessed before.
Last year, astronomers witnessed the brightest explosion on record -- a gamma-ray burst known as GRB 221009A. While this was brighter than AT2021lwx, it lasted for just a fraction of the time, meaning the overall energy released by the AT2021lwx explosion is far greater.
The findings of the research have been published today [Friday, 12 May 2023] in *Monthly Notices of the Royal Astronomical Society.*
Discovery

AT2021lwx was first detected in 2020 by the Zwicky Transient Facility in California, and subsequently picked up by the Asteroid Terrestrial-impact Last Alert System (ATLAS) based in Hawaii. These facilities survey the night sky to detect transient objects that rapidly change in brightness indicating cosmic events such as supernovae, as well as finding asteroids and comets. Until now the scale of the explosion has been unknown.

"We came upon this by chance, as it was flagged by our search algorithm when we were searching for a type of supernova," says Dr Philip Wiseman, Research Fellow at the University of Southampton, who led the research. "Most supernovae and tidal disruption events only last for a couple of months before fading away. For something to be bright for two plus years was immediately very unusual."

The team investigated the object further with several different telescopes: the Neil Gehrels Swift Telescope (a collaboration between NASA, the UK and Italy), the New Technology Telescope (operated by the European Southern Observatory) in Chile, and the Gran Telescopio Canarias in La Palma, Spain.

Measuring the explosion

By analysing the spectrum of the light, splitting it up into different wavelengths and measuring the different absorption and emission features of the spectrum, the team were able to measure the distance to the object.

"Once you know the distance to the object and how bright it appears to us, you can calculate the brightness of the object at its source. Once we'd performed those calculations, we realised this is extremely bright," says Professor Sebastian Hönig from the University of Southampton, a co-author of the research.

The only things in the universe that are as bright as AT2021lwx are quasars -- supermassive black holes with a constant flow of gas falling onto them at high velocity.

Professor Mark Sullivan, also of the University of Southampton and another co-author of the paper, explains: "With a quasar, we see the brightness flickering up and down over time. But looking back over a decade there was no detection of AT2021lwx, then suddenly it appears with the brightness of the brightest things in the universe, which is unprecedented."

What caused the explosion?

There are different theories as to what could have caused such an explosion, but the Southampton-led team believe the most feasible explanation is an extremely large cloud of gas (mostly hydrogen) or dust that has come off course from its orbit around the black hole and been sent flying in.

The team are now setting out to collect more data on the explosion -- measuring different wavelengths, including X-rays which could reveal the object's surface and temperature, and what underlying processes are taking place. They will also carry out upgraded computational simulations to test if these match their theory of what caused the explosion.

Dr Philip Wiseman added: "With new facilities, like the Vera Rubin Observatory's Legacy Survey of Space and Time, coming online in the next few years, we are hoping to discover more events like this and learn more about them. It could be that these events, although extremely rare, are so energetic that they are key processes to how the centres of galaxies change over time."

- Astronomers detect 'nearby' black hole devouring a star

The event was spotted in infrared data -- also a first -- suggesting further searches in this band could turn up more such bursts.

Date: April 28, 2023
Source: Massachusetts Institute of Technology

Illustration of a star being 'spaghettified' by a supermassive black hole. (Image credit: NASA/JPL-Caltech)

Once every 10,000 years or so, the centre of a galaxy lights up as its supermassive black hole rips apart a passing star. This "tidal disruption event" happens in a literal flash, as the central black hole pulls in stellar material and blasts out huge amounts of radiation in the process.

Astronomers know of around 100 tidal disruption events (TDE) in distant galaxies, based on the burst of light that arrives at telescopes on Earth and in space. Most of this light comes from X-rays and optical radiation.

MIT astronomers, tuning past the conventional X-ray and UV/optical bands, have discovered a new tidal disruption event, shining brightly in infrared. It is one of the first times scientists have directly identified a TDE at infrared wavelengths.

What's more, the new outburst happens to be the closest tidal disruption event observed to date: The flare was found in NGC 7392, a galaxy that is about 137 million light-years from Earth, which corresponds to a region in our cosmic backyard that is one-fourth the size of the next-closest TDE.

This new flare, labelled WTP14adbjsh, did not stand out in standard X-ray and optical data. The scientists suspect that these traditional surveys missed the nearby TDE, not because it did not emit X-rays and UV light, but because that light was obscured by an enormous amount of dust that absorbed the radiation and gave off heat in the form of infrared energy.

The researchers determined that WTP14adbjsh occurred in a young, star-forming galaxy, in contrast to the majority of TDEs that have been found in quieter galaxies. Scientists expected that star-forming galaxies should host TDEs, as the stars they churn out would provide plenty of fuel for a galaxy's central black hole to devour. But observations of TDEs in star-forming galaxies were rare until now.

The new study suggests that conventional X-ray and optical surveys may have missed TDEs in star-forming galaxies because these galaxies naturally produce more dust that could obscure any light coming from their core. Searching in the infrared band could reveal many more, previously hidden TDEs in active, star-forming galaxies.

"Finding this nearby TDE means that, statistically, there must be a large population of these events that traditional methods were blind to," says Christos Panagiotou, a postdoc in MIT's Kavli Institute for Astrophysics and Space Research. "So, we should try to find these in infrared if we want a complete picture of black holes and their host galaxies."

A paper detailing the team's discovery appears today in *Astrophysical Journal Letters*. Panagiotou's MIT co-authors are Kishalay De, Megan Masterson, Erin Kara, Michael Calzadilla, Anna-Christina Eilers, Danielle Frostig, Nathan Lourie, and Rob Simcoe, along with Viraj Karambelkar, Mansi Kasliwal, Robert Stein, and Jeffry Zolkower of Caltech, and Aaron Meisner at the National Science Foundation's National Optical-Infrared Astronomy Research Laboratory.

A flash of possibility

Panagiotou did not intend to search for tidal disruption events. He and his colleagues were looking for signs of general transient sources in observational data, using a search tool developed by De. The team used De's method to look for potential transient events in archival data taken by NASA's NEOWISE mission, a space telescope that has made regular scans of the entire sky since 2010, at infrared wavelengths.

The team discovered a bright flash that appeared in the sky near the end of 2014. "We could see there was nothing at first," Panagiotou recalls. "Then suddenly, in late 2014, the source got brighter and by 2015 reached a high luminosity, then started going back to its previous quiescence."

They traced the flash to a galaxy 42 megaparsecs from Earth. The question then was, what set it off? To answer this, the team considered the brightness and timing of the flash, comparing the actual observations with models of various astrophysical processes that could produce a similar flash.

"For instance, supernovae are sources that explode and brighten suddenly, then come back down, on similar timescales to tidal disruption events," Panagiotou notes. "But supernovae are not as luminous and energetic as what we observed."

Working through different possibilities of what the burst could be, the scientists were finally able to exclude all but one: The flash was most likely a TDE, and the closest one observed so far.

"It's a very clean light curve and really follows what we expect the temporal evolution of a TDE should be," Panagiotou says.

Red or green

From there, the researchers took a closer look at the galaxy where the TDE arose. They gathered data from multiple ground- and space-based telescopes which happened to observe the part of the sky where the galaxy resides, across various wavelengths, including infrared, optical, and X-ray bands. With this accumulated data, the team estimated that the supermassive black hole at the centre of the galaxy was about 30 million times as massive as the sun.

"This is almost 10 times larger than the black hole we have at our galactic centre, so it's quite massive, though black holes can get up to 10 billion solar masses," Panagiotou says. The team also found that the galaxy itself is actively producing new stars. Star-forming galaxies are a class of "blue" galaxies, in contrast to quieter "red" galaxies that have stopped producing new stars. Star-forming blue galaxies are the most common type of galaxy in the universe.

"Green" galaxies lie somewhere between red and blue, in that, every so often they produce a few stars. Green is the least common galaxy type, but curiously, most TDEs detected to date have been traced to these rarer galaxies. Scientists had struggled to explain these detections, since theory predicts that blue star-forming galaxies should exhibit TDEs, as they would present more stars for black holes to disrupt.

But star-forming galaxies also produce a lot of dust from the interactions between and among stars near a galaxy's core. This dust is detectable at infrared wavelengths, but it can obscure any X-ray or UV radiation that would otherwise be picked up by optical telescopes. This could explain why astronomers have not detected TDEs in star-forming galaxies using conventional optical methods.

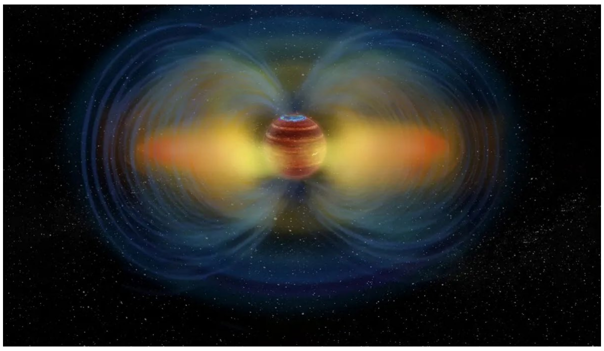
"The fact that optical and X-ray surveys missed this luminous TDE in our own backyard is very illuminating, and demonstrates that these surveys are only giving us a partial census of the total population of TDEs," says Suvi Gezari, associate astronomer and chair of the Science Staff at the Space Telescope Science Institute in Maryland, who was not involved in the study. "Using infrared surveys to catch the dust echo of obscured TDEs…has already shown us that there is a population of TDEs in dusty, star-forming galaxies that we have been missing."

This research was supported, in part, by NASA.

- Astronomers observe the first radiation belt seen outside of our solar system

High-resolution imaging of radio emissions from an ultracool dwarf show a double-lobed structure like the radiation belts of Jupiter

Date: May 15, 2023
Source: University of California - Santa Cruz



Artist's impression of an aurora and the surrounding radiation belt of the ultracool dwarf LSR J1835+3259. Credit: Chuck Carter/Melodie Kao/Heising-Simons Foundation)

Astronomers have described the first radiation belt observed outside our solar system, using a coordinated array of 39 radio dishes from Hawaii to Germany to obtain high-resolution images. The images of persistent, intense radio emissions from an ultracool dwarf reveal the presence of a cloud of high-energy electrons trapped in the object's powerful magnetic field, forming a double-lobed structure analogous to radio images of Jupiter's radiation belts.

"We are actually imaging the magnetosphere of our target by observing the radio-emitting plasma -- its radiation belt -- in the magnetosphere. That has never been done before for something the size of a gas giant planet outside of our solar system," said Melodie Kao, a postdoctoral fellow at UC Santa Cruz and first author of a paper on the new findings published May 15in *Nature*.

Strong magnetic fields form a "magnetic bubble" around a planet called a magnetosphere, which can trap and accelerate particles to near the speed of light. All the planets in our solar system that have such magnetic fields, including Earth, as well as Jupiter and the other giant planets, have radiation belts consisting of these high-energy charged particles trapped by the planet's magnetic field.

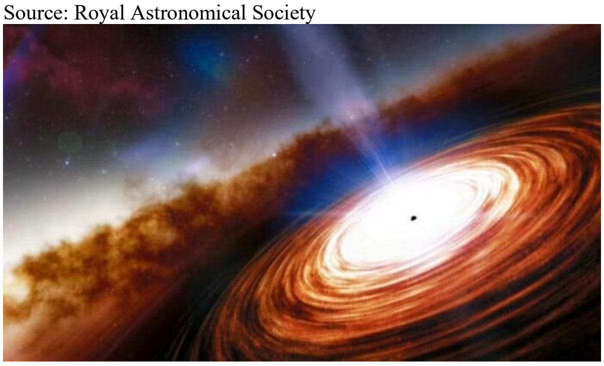
Earth's radiation belts, known as the Van Allen belts, are large donut-shaped zones of high-energy particles captured from solar winds by the magnetic field. Most of the particles in Jupiter's belts are from volcanoes on its moon Io. If you could put them side by side, the radiation belt that Kao and her team have imaged would be 10 million times brighter than Jupiter's.

Particles deflected by the magnetic field toward the poles generate auroras ("northern lights") when they interact with the atmosphere, and Kao's team also obtained the first image capable of differentiating between

the location of an object's aurora and its radiation belts outside our solar system.
The ultracool dwarf imaged in this study straddles the boundary between low-mass stars and massive brown dwarfs. "While the formation of stars and planets can be different, the physics inside of them can be very similar in that mushy part of the mass continuum connecting low-mass stars to brown dwarfs and gas giant planets," Kao explained.
Characterizing the strength and shape of the magnetic fields of this class of objects is largely uncharted terrain, she said. Using their theoretical understanding of these systems and numerical models, planetary scientists can predict the strength and shape of a planet's magnetic field, but they haven't had a good way to easily test those predictions.
"Auroras can be used to measure the strength of the magnetic field, but not the shape. We designed this experiment to showcase a method for assessing the shapes of magnetic fields on brown dwarfs and eventually exoplanets," Kao said.
The strength and shape of the magnetic field can be an important factor in determining a planet's habitability. "When we're thinking about the habitability of exoplanets, the role of their magnetic fields in maintaining a stable environment is something to consider in addition to things like the atmosphere and climate," Kao said.
To generate a magnetic field, a planet's interior must be hot enough to have electrically conducting fluids, which in the case of Earth is the molten iron in its core. In Jupiter, the conducting fluid is hydrogen under so much pressure it becomes metallic. Metallic hydrogen probably also generates magnetic fields in brown dwarfs, Kao said, while in the interiors of stars the conducting fluid is ionized hydrogen.
The ultracool dwarf known as LSR J1835+3259 was the only object Kao felt confident would yield the high-quality data needed to resolve its radiation belts.
"Now that we've established that this particular kind of steady-state, low-level radio emission traces radiation belts in the large-scale magnetic fields of these objects, when we see that kind of emission from brown dwarfs -- and eventually from gas giant exoplanets -- we can more confidently say they probably have a big magnetic field, even if our telescope isn't big enough to see the shape of it," Kao said, adding that she is looking forward to when the Next Generation Very Large Array, currently being planned by the National Radio Astronomy Observatory (NRAO), can image many more extrasolar radiation belts.
"This is a critical first step in finding many more such objects and honing our skills to search for smaller and smaller magnetospheres, eventually enabling us to study those of potentially habitable, Earth-size planets," said co-author Evgenya Shkolnik at Arizona State University, who has been studying the magnetic fields and habitability of planets for many years.
The team used the High Sensitivity Array, consisting of 39 radio dishes coordinated by the NRAO in the United States and the Effelsberg radio telescope operated by the Max Planck Institute for Radio Astronomy in Germany.
"By combining radio dishes from across the world, we can make incredibly high-resolution images to see things no one has ever seen before. Our image is comparable to reading the top row of an eye chart in California while standing in Washington, D.C.," said co-author Jackie Villadsen at Bucknell University.
Kao emphasized that this discovery was a true team effort, relying heavily on the observational expertise of co-first author Amy Mioduszewski at NRAO in planning the study and analysing the data, as well as the multiwavelength stellar flare expertise of Villadsen and Shkolnik. This work was supported by NASA and the Heising-Simons Foundation.

- An X-ray look at the heart of powerful quasars

Date: May 19, 2023
Source: Royal Astronomical Society


Artist’s impression of a quasar NOIRLab/NSF/AURA/J. da Silva

Researchers have observed the X-ray emission of the most luminous quasar seen in the last 9 billion years of cosmic history, known as SMSS J114447.77-430859.3, or J1144 for short. The new perspective sheds light on the inner workings of quasars and how they interact with their environment. The research is published in *Monthly Notices of the Royal Astronomical Society.*

Hosted by a galaxy 9.6 billion light years away from the Earth, between the constellations of Centaurus and Hydra, J1144 is extremely powerful, shining 100,000 billion times brighter than the Sun. J1144 is much closer to Earth than other sources of the same luminosity, allowing astronomers to gain insight into the black hole powering the quasar and its surrounding environment. The study was led by Dr Elias Kammoun, a postdoctoral researcher at the Research Institute in Astrophysics and Planetology (IRAP), and Zsofi Igo, a PhD candidate at the Max Planck Institute for Extra-terrestrial Physics (MPE).

Quasars are among the brightest and most distant objects in the known universe, powered by the fall of gas into a supermassive black hole. They can be described as active galactic nuclei (AGN) of very high luminosity that emit vast amounts of electromagnetic radiation observable in radio, infrared, visible, ultraviolet and X-ray wavelengths. J1144 was initially observed in visible wavelengths in 2022 by the SkyMapper Southern Survey (SMSS).

For this study, researchers combined observations from several space-based observatories: the eROSITA instrument on board the Spectrum-Roentgen-Gamma (SRG) observatory, the ESA XMM-Newton observatory, NASA's Nuclear Spectroscopic Telescope Array (NuSTAR), and NASA's Neil Gehrels Swift observatory.

The team used the data from the four observatories to measure the temperature of the X-rays being emitted from the quasar. They found this temperature to be around 350 million Kelvin, more than 60,000 times the temperature at the surface of the Sun. The team also found that the mass of the black hole at the quasar's centre is around 10 billion times the mass of the Sun, and the rate at which it is growing to be of the order of 100 solar masses per year.

The X-ray light from this source varied on a time scale of a few days, which is not usually seen in quasars with black holes as large as the one residing in J1144. The typical timescale of variability for a black hole of this size would be on the order of months or even years. The observations also showed that while a portion of the gas is swallowed by the black hole, some gas is ejected in the form of extremely powerful winds, injecting large amounts of energy into the host galaxy.

Dr. Kammoun, lead author of the paper, says "We were very surprised that no prior X-ray observatory has ever observed this source despite its extreme power."

He adds, "Similar quasars are usually found at much larger distances, so they appear much fainter, and we see them as they were when the Universe was only 2-3 billion years old. J1144 is a very rare source as it is so luminous and much closer to Earth (although still at a huge distance!), giving us a unique glimpse of what such powerful quasars look like."

"A new monitoring campaign of this source will start in June this year, which may reveal more surprises from this unique source."

- ❖ Radio signal reveals supernova origin

Date: May 17, 2023
Source: Stockholm University

Artist's impression of helium-rich material from a companion star accreting onto a white dwarf. Before the explosion, a large amount of material is stripped from the companion. The research team hopes to clarify the relationship between the emitted strong radio waves and this stripped material. Credit: Adam Makarenko/W. M. Keck Observatory

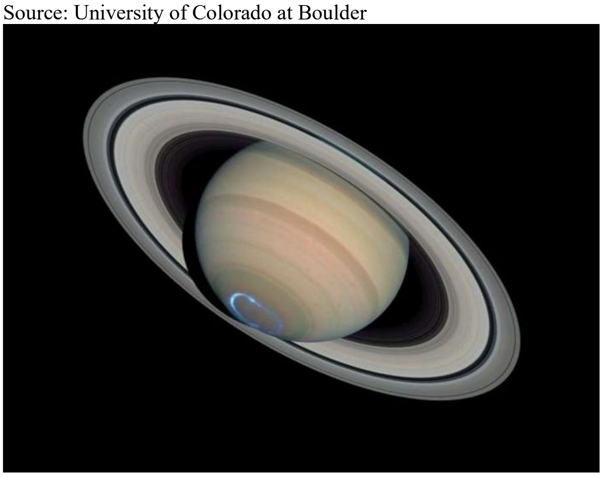
In the latest issue of the journal *Nature*, astronomers from Stockholm University reveal the origin of a thermonuclear supernova explosion. Strong emission lines of helium and the first detection of such a supernova in radio waves show that the exploding white dwarf star had a helium-rich companion.

Supernovae of Type Ia are important for astronomers since they are used to measure the expansion of the Universe. However, the origin of these explosions has remained an open question. While it is established that the explosion is that of a compact white dwarf star somehow accreting too much matter from a companion star, the exact process and the nature of the progenitor is not known. The new discovery of supernova SN 2020eyj established that the companion star was a helium star that had lost much of its material just prior to the explosion of the white dwarf.

"Once we saw the signatures of strong interaction with the material from the companion we tried to also detect it in radio emission," explains Erik Kool, post-doc at the Department of Astronomy at Stockholm university and lead author of the paper. "The detection in radio is the first one of a Type Ia supernova -- something astronomers have tried to do for decades."
Supernova 2020eyj was discovered by the Zwicky Transient Facility camera on Palomar mountain, where the Oskar Klein Centre at Stockholm University are members.
"The Nordic Optical telescope on La Palma was fundamental for following up this supernova," says Professor Jesper Sollerman at the Department of Astronomy and co-author of the paper. "As were spectra from the large Keck telescope on Hawai'i that immediately revealed the very unusual helium-dominated material around the exploded star."
"This is clearly a very unusual Type Ia supernova, but still related to the ones we use to measure the expansion of the universe," adds Joel Johansson from the Department of Physics.
"While normal Type Ia supernovae appear to always explode with the same brightness, this supernova tells us that there are many different pathways to a white dwarf star explosion," he adds.

- ❖ New study puts a definitive age on Saturn's rings -- they're really young

Date: May 12, 2023
Source: University of Colorado at Boulder


Credit: Pixabay/CC0 Public Domain

A new study led by physicist Sascha Kempf at the University of Colorado Boulder has delivered the strongest evidence yet that Saturn's rings are remarkably young -- potentially answering a question that has boggled scientists for well over a century.
The research, to be published May 12 in the journal *Science Advances,* pegs the age of Saturn's rings at no more than 400 million years old. That makes the rings much younger than Saturn itself, which is about 4.5 billion years old.
"In a way, we've gotten closure on a question that started with James Clerk Maxwell," said Kempf, associate professor in the Laboratory for Atmospheric and Space Physics (LASP) at CU Boulder.
The researchers arrived at that closure by studying what might seem like an unusual subject: dust.
Kempf explained that tiny grains of rocky material wash through Earth's solar system on an almost constant basis. In some cases, this flux can leave behind a thin layer of dust on planetary bodies, including on the ice that makes up Saturn's rings.
In the new study, he and his colleagues set out to put a date on Saturn's rings by studying how rapidly this layer of dust builds up -- a bit like telling how old a house is by running your finger along its surfaces.
"Think about the rings like the carpet in your house," Kempf said. "If you have a clean carpet laid out, you just have to wait. Dust will settle on your carpet. The same is true for the rings."
It was an arduous process: From 2004 to 2017, the team used an instrument called the Cosmic Dust Analyzer aboard NASA's late Cassini spacecraft to analyse specks of dust flying around Saturn. Over those 13 years, the researchers collected just 163 grains that had originated from beyond the planet's close neighbourhood. But it was enough. Based on their calculations, Saturn's rings have likely been gathering dust for only a few hundred million years.
The planet's rings, in other words, are new phenomena, arising (and potentially even disappearing) in what amounts to a blink of an eye in cosmic terms.
"We know approximately how old the rings are, but it doesn't solve any of our other problems," Kempf said. "We still don't know how these rings formed in the first place."
From Galileo to Cassini
Researchers have been captivated by these seemingly-translucent rings for more than 400 years. In 1610, Italian astronomer Galileo Galilei first observed the features through a telescope, although he didn't know what they were. (Galileo's original drawings make the

rings look a bit like the handles on a water jug). In the 1800s, Maxwell, a scientist from Scotland, concluded that Saturn's rings couldn't be solid but were, instead, made up of many individual pieces.
Today, scientists know that Saturn hosts seven rings comprised of countless chunks of ice, most no bigger than a boulder on Earth. Altogether, this ice weighs about half as much as Saturn's moon Mimas and stretches nearly 175,000 miles from the planet's surface.
Kempf added that for most of the 20th Century, scientists assumed that the rings likely formed at the same time as Saturn. But that idea raised a few issues -- namely, Saturn's rings are sparkling clean. Observations suggest that these features are made up of roughly 98% pure water ice by volume, with only a tiny amount of rocky matter.
"It's almost impossible to end up with something so clean," Kempf said.
Cassini offered an opportunity to put a definitive age on Saturn's rings. The spacecraft first arrived at Saturn in 2004 and collected data until it purposefully crashed into the planet's atmosphere in 2017. The Cosmic Dust Analyzer, which was shaped a bit like a bucket, scooped up small particles as they whizzed by.
Engineers and scientists at LASP designed and built a much more sophisticated dust analyser for NASA's upcoming Europa Clipper mission, which is scheduled to launch in 2024.
The team estimated that this interplanetary grime would contribute far less than a gram of dust to each square foot of Saturn's rings every year -- a light sprinkle, but enough to add up over time. Previous studies had also suggested that the rings could be young but didn't include definitive measures of dust accumulation.

Stroke of luck

The rings might already be vanishing. In a previous study, NASA scientists reported that the ice is slowly raining down onto the planet and could disappear entirely in another 100 million years.
That these ephemeral features existed at a time when Galileo and the Cassini spacecraft could observe them seems almost too good to be true, Kempf said -- and it begs an explanation for how the rings formed in the first place. Some scientists, for example, have posited that Saturn's rings may have formed when the planet's gravity tore apart one of its moons.
"If the rings are short lived and dynamical, why are we seeing them now?" he said. "It's too much luck."
Co-authors on the new study include Nicolas Altobelli of the European Space Agency; Jürgen Schmidt of the Freie Universität Berlin; Jeffrey Cuzzi and Paul Estrada of the NASA Ames Research Centre; and Ralf Srama of the Universität Stuttgart.

- Researchers find new approach to explore earliest universe dynamics with gravitational waves

Date: May 11, 2023
Source: Kavli Institute for the Physics and Mathematics of the Universe

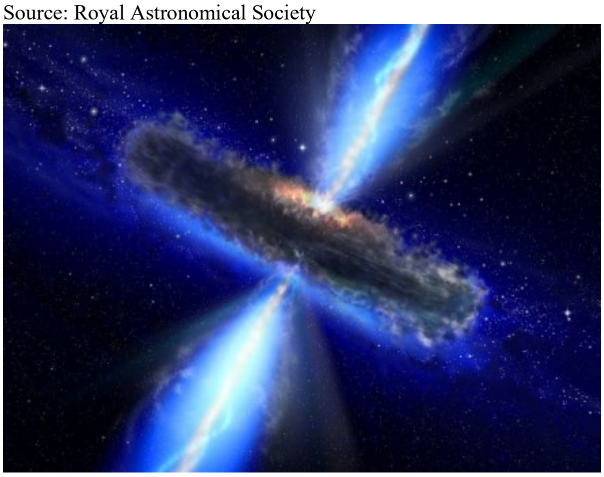
Gravitational waves Sakkmesterke/iStock

Researchers have discovered a new generic production mechanism of gravitational waves generated by a phenomenon known as oscillons, which can originate in many cosmological theories from the fragmentation into solitonic "lumps" of the inflation field that drove the early Universe's rapid expansion, reports a new study published in *Physical Review Letters*.
The results have set the stage for revealing exciting novel insights about the Universe's earliest moments.
The inflationary period, which occurred just after the Big Bang, is believed to have caused the Universe to expand exponentially. In many cosmological theories, the rapid expansion period is followed by the formation of oscillons. Oscillons are a type of localized non-linear massive structure that can form from fields, such as the inflation field, which are oscillating at high frequencies. These structures can persist for long periods, and as the researchers found, their eventual decay can generate a significant number of gravitational waves, which are ripples in space-time.
In their study, Kavli Institute for the Physics and Mathematics of the Universe (Kavli IPMU) Project Researcher Kaloian D.

Lozanov, and Kavli IPMU Visiting Associate Scientist, International Centre for Quantum-field Measurement Systems for Studies of the Universe and Particles (QUP) Senior Scientist, and High Energy Accelerator Research Organization (KEK) Theory Centre Assistant Professor Volodymyr Takhistov, simulated the evolution of the inflation field during the early Universe and found that oscillons were indeed present. They then found that oscillon decay was able to generate gravitational waves that would be detectable by upcoming gravitational wave observatories.
The findings provide a novel test of the early Universe dynamics independent of the conventionally studied cosmic microwave background radiation. The discovery of these gravitational waves would establish a new window into the Universe's earliest moments, and could help shed light on some of the pressing fundamental questions in cosmology.
With the ongoing development of gravitational wave detectors and supercomputing resources, we can expect to gain even more insights into the Universe's early moments in the coming years. Overall, the new study demonstrates the power of combining theoretical models with advanced computational techniques and observations to uncover new insights into the Universe's evolution.
Details of their study were published in *Physical Review Letters* on May 2.

- ❖ Hidden supermassive black holes brought to life by galaxies on collision course

Date: May 11, 2023
Source: Royal Astronomical Society



Credit: ESA/NASA, the AVO project and Paolo Padovani

Astronomers have found that supermassive black holes obscured by dust are more likely to grow and release tremendous amounts of energy when they are inside galaxies that are expected to collide with a neighbouring galaxy. The new work, led by researchers from Newcastle University, is published in *Monthly Notices of the Royal Astronomical Society.*
Galaxies, including our own Milky Way, contain supermassive black holes at their centres. They have masses equivalent to millions, or even billions, times that of our Sun. These black holes grow by ‘eating’ gas that falls on to them. However, what drives the gas close enough to the black holes for this to happen is an ongoing mystery.
One possibility is that when galaxies are close enough together, they are likely to be gravitationally pulled towards each other and ‘merge’ into one larger galaxy.
In the final stages of its journey into a black hole, gas lights up and produces a huge amount of energy. This energy is typically detected using visible light or X-rays. However, the astronomers conducting this study were only able to detect the growing black holes using infrared light. The team made use of data from many different telescopes, including the Hubble Space Telescope and infrared Spitzer Space Telescope.
The researchers developed a new technique to determine how likely it is that two galaxies are very close together and are expected to collide in the future. They applied this new method to hundreds of thousands of galaxies in the distant universe (looking at galaxies formed 2 to 6 billion years after the Big Bang) in an attempt to better understand the so-called ‘cosmic noon’, a time when most of the Universe’s galaxy and black hole growth is expected to have taken place.
Understanding how black holes grew during this time is fundamental in modern day galactic research, especially as it may give us an insight into the supermassive black hole situated inside the Milky Way, and how our galaxy evolved over time.
As they are so far away, only a small number of cosmic noon galaxies meet the required criteria to get precise measurements of their distances. This makes it very difficult to know with high precision if any two galaxies are very close to each other.
This study presents a new statistical method to overcome the previous limitations of measuring accurate distances of galaxies and supermassive black holes at cosmic noon. It applies a statistical approach to determine

galaxy distances using images at different wavelengths and removes the need for spectroscopic distance measurements for individual galaxies.

Data arriving from the James Webb Space Telescope over the coming years is expected to revolutionise studies in the infrared and reveal even more secrets about how these dusty black holes grow.

Sean Dougherty, postgraduate student at Newcastle University and lead author of the paper, says, “Our novel approach looks at hundreds of thousands of distant galaxies with a statistical approach and asks how likely any two galaxies are to be close together and so likely to be on a collision course.”

Dr Chris Harrison, co-author of the study, “These supermassive black holes are very challenging to find because the X-ray light, which astronomers have typically used to find these growing black holes, is blocked, and not detected by our telescopes. But these same black holes can be found using infrared light, which is produced by the hot dust surrounding them.”

He adds, “The difficulty in finding these black holes and in establishing precise distance measurements explains why this result has previously been challenging to pin down these distant ‘cosmic noon’ galaxies. With JWST we are expecting to find many more of these hidden growing black holes. JWST will be far better at finding them, therefore we will have many more to study, including ones that are the most difficult to find. From there, we can do more to understand the dust that surrounds them, and find out how many are hidden in distant galaxies.”

- ❖ Celestial monsters at the origin of globular clusters

Date: May 11, 2023
Source: Université de Genève

The globular cluster Messier 13, or the Hercules Cluster, as seen by the Hubble Space Telescope. Somewhere at the heart of this dense stellar crowd may lie cosmic monsters known as superstars. (Image credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA); Acknowledgment: C. Bailyn (Yale University), W. Lewin (Massachusetts Institute of Technology), A. Sarajedini (University of Florida), and W. van Altena (Yale University))

Globular clusters are the most massive and oldest star clusters in the Universe. They can contain up to 1 million of them. The chemical composition of these stars, born at the same time, shows anomalies that are not found in any other population of stars. Explaining this specificity is one of the great challenges of astronomy. After having imagined that supermassive stars could be at the origin, a team from the Universities of Geneva and Barcelona, and the Institut d'Astrophysique de Paris (CNRS and Sorbonne University) believes it has discovered the first chemical trace attesting to their presence in globular proto-clusters, born about 440 million years after the Big Bang. These results, obtained thanks to observations by the James-Webb space telescope, are to be found in *Astronomy and Astrophysics*.

Globular clusters are very dense groupings of stars distributed in a sphere, with a radius varying from a dozen to a hundred light years. They can contain up to 1 million stars and are found in all types of galaxies. Ours is home to about 180 of them. One of their great mysteries is the composition of their stars: why is it so varied? For instance, the proportion of oxygen, nitrogen, sodium and aluminium varies from one star to another. However, they were all born at the same time, within the same cloud of gas. Astrophysicists speak of "abundance anomalies".

Monsters with very short lives

A team from the universities of Geneva (UNIGE) and Barcelona, and the Institut d'Astrophysique de Paris (CNRS and Sorbonne University) has made a new advance in the explanation of this phenomenon. In 2018, it had developed a theoretical model according to which supermassive stars would have "polluted" the original gas cloud during the formation of these clusters, enriching their stars with chemical elements in a heterogeneous manner. "Today, thanks to the data collected by the James-Webb Space Telescope, we believe we have found a first clue of the presence of these extraordinary stars," explains Corinne Charbonnel, a full professor in the Department of Astronomy at the UNIGE Faculty of Science, and first author of the study.

These celestial monsters are 5,000 to 10,000 times more massive and five times hotter at their centre (75 million °C) than the Sun. But proving their existence is complex. "Globular clusters are between 10 and 13 billion years old, whereas the maximum lifespan of superstars is two million years. They therefore disappeared very early from the clusters that are currently observable. Only indirect traces remain," explains Mark Gieles, ICREA professor at the University of Barcelona and co-author of the study.

Revealed by light

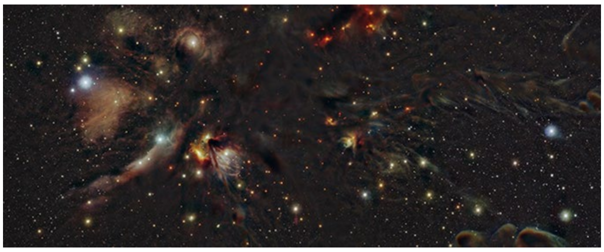
Thanks to the very powerful infrared vision of the James-Webb telescope, the co-authors were able to support their hypothesis. The satellite captured the light emitted by one of the most distant and youngest galaxies known to date in our Universe. Located at about 13.3 billion light-years, GN-z11 is only a few tens of millions of years old. In astronomy, the analysis of the light spectrum of cosmic objects is a key element in determining their characteristics. Here, the light emitted by this galaxy has provided two valuable pieces of information.

"It has been established that it contains very high proportions of nitrogen and a very high density of stars," says Daniel Schaerer, associate professor in the Department of Astronomy at the UNIGE Faculty of Science, and co-author of the study. This suggests that several globular clusters are forming in this galaxy and that they still harbour an active supermassive star. "The strong presence of nitrogen can only be explained by the combustion of hydrogen at extremely high temperatures, which only the core of supermassive stars can reach, as shown by the models of Laura Ramirez-Galeano, a Master's student in our team," explains Corinne Charbonnel.

These new results strengthen the international team's model. The only one currently capable of explaining the abundance anomalies in globular clusters. The next step for the scientists will be to test the validity of this model on other globular clusters forming in distant galaxies, using the James-Webb data.

- ❖ Hidden views of vast stellar nurseries

Date: May 11, 2023
Source: ESO



Using ESO’s Visible and Infrared Survey Telescope for Astronomy (VISTA), astronomers have created a vast infrared atlas of five nearby stellar nurseries by piecing together more than one million images. These large mosaics reveal young stars in the making, embedded in thick clouds of dust. Thanks to these observations, astronomers have a unique tool with which to decipher the complex puzzle of stellar birth.

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"In these images we can detect even the faintest sources of light, like stars far less massive than the Sun, revealing objects that no one has ever seen before," says Stefan Meingast, an astronomer at the University of Vienna in Austria and lead author of the new study published today in Astronomy & Astrophysics. "This will allow us to understand the processes that transform gas and dust into stars."

Stars form when clouds of gas and dust collapse under their own gravity, but the details of how this happens are not fully understood. How many stars are born out of a cloud? How massive are they? How many stars will also have planets?

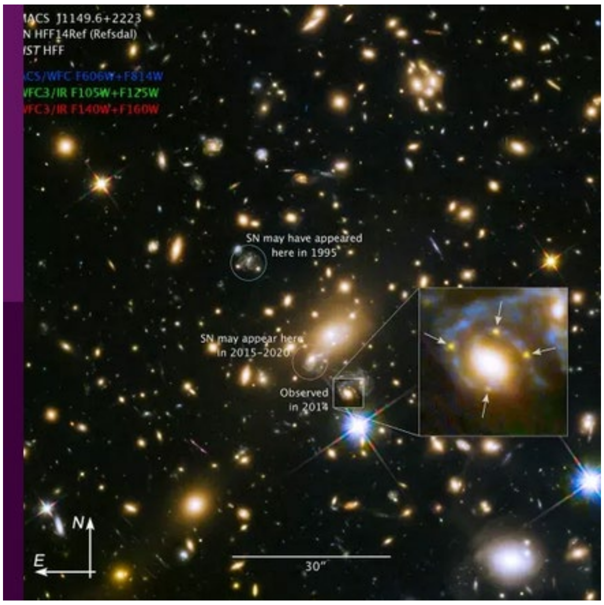
To answer these questions, Meingast's team surveyed five nearby star-forming regions with the VISTA telescope at ESO's Paranal Observatory in Chile. Using VISTA's infrared camera VIRCAM, the team captured light coming from deep inside the clouds of dust. "The dust obscures these young stars from our view, making them virtually invisible to our eyes. Only at infrared wavelengths can we look deep into these clouds, studying the stars in the making," explains Alena Rottensteiner, a PhD student also at the University of Vienna and co-author of the study.

The survey, called VISIONS, observed star-forming regions in the constellations of Orion, Ophiuchus, Chamaeleon, Corona Australis and Lupus. These regions are less than 1500 light-years away and so large that they span a huge area in the sky. The diameter of

VIRCAM's field of view is as wide as three full Moons, which makes it uniquely suited to map these immensely big regions.
The team obtained more than one million images over a period of five years. The individual images were then pieced together into the large mosaics released here, revealing vast cosmic landscapes. These detailed panoramas feature dark patches of dust, glowing clouds, newly-born stars and the distant background stars of the Milky Way. Since the same areas were observed repeatedly, the VISIONS data will also allow astronomers to study how young stars move. "With VISIONS we monitor these baby stars over several years, allowing us to measure their motion and learn how they leave their parent clouds," explains João Alves, an astronomer at the University of Vienna and Principal Investigator of VISIONS. This is not an easy feat, as the apparent shift of these stars as seen from Earth is as small as the width of a human hair seen from 10 kilometres away. These measurements of stellar motions complement those obtained by the European Space Agency's Gaia mission at visible wavelengths, where young stars are hidden by thick veils of dust.
The VISIONS atlas will keep astronomers busy for years to come. "There is tremendous long-lasting value for the astronomical community here, which is why ESO steers Public Surveys like VISIONS," says Monika Petr-Gotzens, an astronomer at ESO in Garching, Germany, and co-author of this study. Moreover, VISIONS will set the groundwork for future observations with other telescopes such as ESO's Extremely Large Telescope (ELT), currently under construction in Chile and set to start operating later this decade. "The ELT will allow us to zoom into specific regions with unprecedented detail, giving us a never-seen-before close-up view of individual stars that are currently forming there," concludes Meingast.

- Measurement of the Universe's expansion rate weighs in on a longstanding debate in physics and astronomy

Date: May 11, 2023
Source: University of Minnesota



Thanks to data from a magnified, multiply imaged supernova, a team led by University of Minnesota Twin Cities researchers has successfully used a first-of-its-kind technique to measure the expansion rate of the Universe. Their data provide insight into a longstanding debate in the field and could help scientists more accurately determine the Universe's age and better understand the cosmos.
The work is divided into two papers, respectively published in *Science*, one of the world's top peer-reviewed academic journals, and *The Astrophysical Journal*, a peer-reviewed scientific journal of astrophysics and astronomy.
In astronomy, there are two precise measurements of the expansion of the Universe, also called the "Hubble constant." One is calculated from nearby observations of supernovae, and the second uses the "cosmic microwave background," or radiation that began to stream freely through the Universe shortly after the Big Bang.
However, these two measurements differ by about 10 percent, which has caused widespread debate among physicists and astronomers. If both measurements are accurate, that means scientists' current theory about the make-up of the universe is incomplete.
"If new, independent measurements confirm this disagreement between the two measurements of the Hubble constant, it would become a chink in the armour of our understanding of the cosmos," said Patrick Kelly, lead author of both papers and an assistant professor in the University of Minnesota School of Physics and Astronomy. "The big question is if there is a possible issue with one or both of the measurements. Our

research addresses that by using an independent, completely different way to measure the expansion rate of the Universe."

The University of Minnesota-led team was able to calculate this value using data from a supernova discovered by Kelly in 2014 -- the first ever example of a multiply imaged supernova, meaning that the telescope captured four different images of the same cosmic event. After the discovery, teams around the world predicted that the supernova would reappear at a new position in 2015, and the University of Minnesota team detected this additional image.

These multiple images appeared because the supernova was gravitationally lensed by a galaxy cluster, a phenomenon in which mass from the cluster bends and magnifies light. By using the time delays between the appearances of the 2014 and 2015 images, the researchers were able to measure the Hubble Constant using a theory developed in 1964 by Norwegian astronomer Sjur Refsdal that had previously been impossible to put into practice.

The researchers' findings don't absolutely settle the debate, Kelly said, but they do provide more insight into the problem and bring physicists closer to obtaining the most accurate measurement of the Universe's age.

"Our measurement favours the value from the cosmic microwave background, although it is not in strong disagreement with the supernova value," Kelly said. "If observations of future supernovae that are also gravitationally lensed by clusters yield a similar result, then it would identify an issue with the current supernova value, or with our understanding of galaxy-cluster dark matter."

Using the same data, the researchers found that some current models of galaxy-cluster dark matter were able to explain their observations of the supernovae. This allowed them to determine the most accurate models for the locations of dark matter in the galaxy cluster, a question that has long plagued astronomers.

This research was funded primarily by NASA through the Space Telescope Science Institute and the National Science Foundation.

In addition to Kelly, the team included researchers from the University of Minnesota's Minnesota Institute for Astrophysics; the University of South Carolina; the University of California, Los Angeles; Stanford University; the Swiss Federal Institute of Technology Lausanne; Sorbonne University; the University of California, Berkeley; the University of Toronto; Rutgers University; the University of Copenhagen; the University of Cambridge; the Kavli Institute for Cosmology; Ben-Gurion University of the Negev; University of the Basque Country; the University of Cantabria; Consejo Superior de Investigaciones Cientificas (the Spanish National Research Council); the Observatories of the Carnegie Institution for Science; the University of Portsmouth; Durham University; the University of California, Santa Barbara; the University of Tokyo; the Space Telescope Science Institute; the Leibniz Institute for Astrophysics Potsdam; the University of Michigan; Australian National University; Stony Brook University; Heidelberg University; and Chiba University.

- ❖ Astronomers find no young binary stars near Milky Way's black hole

Date: May 11, 2023
Source: University of California - Los Angeles

The binary stars of the nearby Alpha Centauri system, as seen by NASA's Hubble Space Telescope. On the left is Alpha Centauri A, which is a sun-like G-type star. On the right is Alpha Centauri B, which is a slightly cooler K-type star. (Image credit: ESA/NASA)

When supermassive stars are born, they're almost always paired with a twin, and the two stars normally orbit one another.

But astronomers at UCLA's Galactic Centre Group and the Keck Observatory have analysed over a decade's worth of data about 16 young supermassive stars orbiting the supermassive black hole at the centre of the Milky Way galaxy. Their findings, published today in the *Astrophysical Journal*, reveal a startling conclusion: All of them are singletons.

But why? Are the stars, which are about 10 times larger than our sun, being formed alone in the hostile environment around the black hole? Have their "twins" been kicked out by the black hole? Or have pairs of stars merged to form single stars?

The findings support a scenario in which the central supermassive black hole drives nearby stellar binaries to merge or be disrupted, with one of the pair being ejected from the system. The stars the scientists observed are known as S-stars, and most of them are young -- formed within the past 6 million years -- and massive. They are mostly located within a light-month, or a little under 500 billion miles, of the black hole.

"Stars this young shouldn't even be near the black hole in the first place," said UCLA postdoctoral scholar Devin Chu, the study's first author. "They couldn't have migrated to this region in just 6 million years. But to have a star form in such a hostile environment is surprising."

Chu and his colleagues used data taken with Keck's adaptive optics instruments to conduct the first-ever search for spectroscopic binary stars among the S-stars. Spectroscopic binary stars appear through optical telescopes to be single stars but, when the light they emit is analysed by scientists, are revealed to actually be pairs of stars.

All of the S-stars that appeared to be single were, in fact, alone.

Even more surprising, the researchers found that the number of pairs of S-stars that could possibly exist near the black hole was much lower than the number of comparable stars in the section of space surrounding Earth's sun, known as the solar neighbourhood.

They did this by calculating a metric called the binary fraction, which defines how many stars in a given area could come in pairs; the higher the binary fraction, the more stars that could exist in pairs. Previous studies have shown that the binary fraction for stars similar to S-stars in Earth's solar neighbourhood is around 70%. In the new study, the researchers found that near the Milky Way's black hole, the upper limit is just 47% -- suggesting that the extreme environment of the black hole is limiting the survival of stellar binaries.

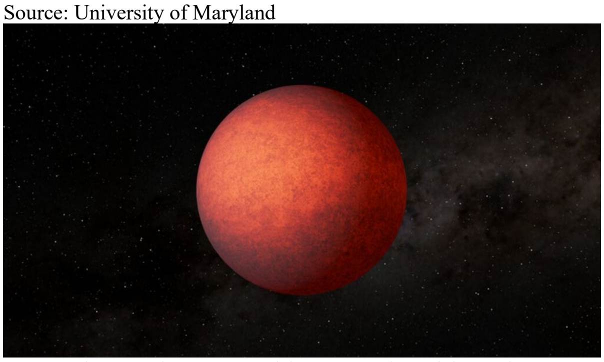
"This difference speaks to the incredibly interesting environment of the centre of our galaxy; we're not dealing with a normal environment here," Chu said. "This also suggests that the black hole drives these nearby binary stars to merge or be disrupted, which has important implications for the production of gravitational waves and hypervelocity stars ejected from the galactic centre."

The UCLA researchers now plan to explore how the limit on the binary fraction they calculated compares to the binary fraction for similar stars that are located farther from the black hole, but still within its gravitational influence.

- ❖ Researchers measure the light emitted by a sub-Neptune planet's atmosphere

Astronomers say exoplanet GJ 1214b is too hot to be habitable but likely contains water vapor

Date: May 10, 2023
Source: University of Maryland



U-M graduate student Isaac Malsky, a co-author of the study, ran three-dimensional models for the planet, testing models with and without clouds and hazes, to see how these aerosols shape the thermal structure of the planet and help interpret the data. Image credit: NASA/JPL-Caltech/R. Hurt (IPAC)

For more than a decade, astronomers have been trying to get a closer look at GJ 1214b, an exoplanet 40 light-years away from Earth. Their biggest obstacle is a thick layer of haze that blankets the planet, shielding it from the probing eyes of space telescopes and stymying efforts to study its atmosphere.

NASA's new James Webb Space Telescope (JWST) solved that issue. The telescope's infrared technology allows it to see planetary objects and features that were previously obscured by hazes, clouds or space dust, aiding astronomers in their search for habitable planets and early galaxies.

A team of researchers used JWST to observe GJ 1214b's atmosphere by measuring the heat it emits while orbiting its host star. Their results, published in the journal *Nature* on May 10, 2023, represent the first time anyone has directly detected the light emitted by a sub-Neptune exoplanet -- a category of planets that are larger than Earth but smaller than Neptune.

Though GJ 1214b is far too hot to be habitable, researchers discovered that its atmosphere likely contains water vapor -- possibly even significant amounts -- and is primarily composed of molecules heavier than hydrogen. University of Maryland Associate Professor of Astronomy Eliza Kempton, lead author of the *Nature* study, said their findings mark a turning point in the study of sub-Neptune planets like GJ 1214b.

"I've been on a quest to understand GJ 1214b for more than a decade," Kempton said. "When we received the data for this *Nature* paper, we could see the light from the planet just disappear when it went behind its host star. That had never before been seen for this planet or for any other planet of its class, so JWST is really delivering on its promise."

A 'new light'

Sub-Neptunes are the most common type of planet in the Milky Way, though none exist in our solar system. Despite the murkiness of GJ 1214b's atmosphere, Kempton and her co-authors determined the planet was still their best chance of observing a sub-Neptune's atmosphere because of its bright but small host star.

In their *Nature* paper, the researchers measured the infrared light that GJ 1214b emitted over the course of about 40 hours -- the time it takes the planet to orbit its star. As day turns to night, the amount of heat that shifts from one side of a planet to the other depends largely on what its atmosphere is made of. Known as a phase curve observation, this research method opened a new window into the planet's atmosphere.

"JWST operates at longer wavelengths of light than previous observatories, which gives us access to the heat emitted by the planet and allows us to create a map of the planet's temperature," Kempton said. "We finally got to see GJ 1214b in a new light."

By measuring the movement and fluctuation of heat, the researchers determined that GJ 1214b does not have an atmosphere dominated by hydrogen.

Potential water world?

The question of whether GJ 1214b contains water has long interested astronomers. Previous observations by NASA's Hubble Space Telescope suggested that GJ 1214b could be a water world -- a loose term for any planet that contains a significant amount of water.

The latest JWST data revealed traces of water, methane or some mix of the two. These substances match a subtle absorption of light seen in the wavelength range observed by JWST. Further studies will be needed to determine the exact makeup of the planet's atmosphere, but Kempton said the evidence remains consistent with the possibility of large amounts of water.

"GJ 1214b, based on our observations, could be a water world," Kempton said. "We think we detect water vapor, but it's challenging because water vapor absorption overlaps with methane absorption, so we can't say 100% that we detected water vapor and not methane. However, we see this evidence on both hemispheres of the planet, which heightens our confidence that there really is water there."

Reflecting on the findings

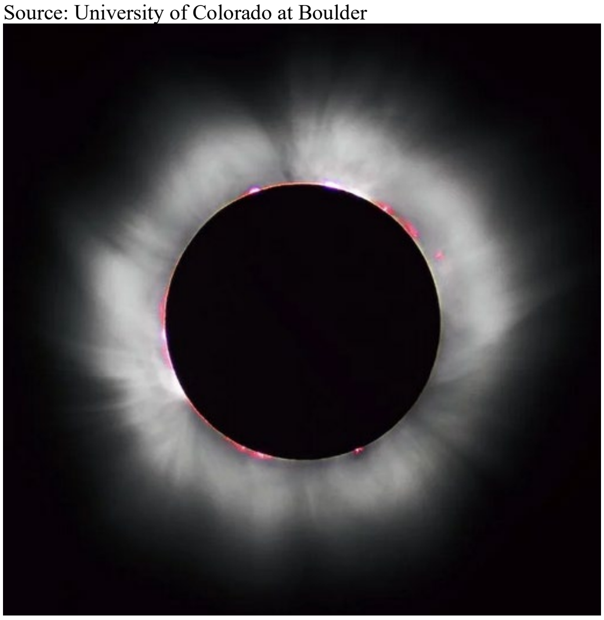
The researchers made another surprising discovery in their study: GJ 1214b is incredibly reflective. The planet was not as hot as expected, which tells researchers that something in the atmosphere is reflecting light.

Kempton said there is plenty of room for follow-up studies, including ones that take a closer look at the high-altitude aerosols that form the haze -- or possibly clouds -- in GJ 1214b's atmosphere. Previously, researchers thought it might be a dark, soot-like substance that absorbs light. However, the discovery that the exoplanet is reflective raises new questions.

"Whatever is making up the hazes or clouds is not what we expected. It's bright, it's reflective and that's confusing and surprising," Kempton said. "This is going to point us toward a lot of further studies to try to understand what those hazes could be."

- How 1,000 undergraduates helped solve an enduring mystery about the sun

Date: May 9, 2023
Source: University of Colorado at Boulder



Radiation streaming from the sun's corona becomes visible during an eclipse

For a new study, a team of physicists recruited roughly 1,000 undergraduate students at the University of Colorado Boulder to help

answer one of the most enduring questions about the sun: How does the star's outermost atmosphere, or "corona," get so hot?
The research represents a nearly-unprecedented feat of data analysis: From 2020 to 2022, the small army of mostly first- and second-year students examined the physics of more than 600 real solar flares -- gigantic eruptions of energy from the sun's roiling corona.
The researchers, including 995 undergraduate and graduate students, published their finding May 9 in *The Astrophysical Journal*. The results suggest that solar flares may not be responsible for superheating the sun's corona, as a popular theory in astrophysics suggests.
"We really wanted to emphasize to these students that they were doing actual scientific research," said James Mason, lead author of the study and an astrophysicist at the Johns Hopkins University Applied Physics Laboratory.
Study co-author Heather Lewandowski agreed, noting that the study wouldn't be possible without the undergrads who contributed an estimated 56,000 hours of work to the project.
"It was a massive effort from everyone involved," said Lewandowski, professor of physics and fellow of JILA, a joint research institute between CU Boulder and the National Institute of Standards and Technology (NIST).
Campfire physics
The study zeroes in on a mystery that has left even senior astrophysicists scratching their heads.
Telescope observations suggest that the sun's corona sizzles at temperatures of millions of degrees Fahrenheit. The surface of the sun, in contrast, is much cooler, registering only in the thousands of degrees.
"That's like standing right in front of a campfire, and as you back away, it gets a lot hotter," Mason said. "It makes no sense."
Some scientists suspect that especially tiny flares, or "nanoflares," which are too small for even the most advanced telescopes to spot, may be responsible. If such events exist, they may pop up across the sun on a nearly constant basis. And, the theory goes, they could add up to make the corona toasty. Think of boiling a pot of water using thousands of individual matches.
The students' results cast doubt on this theory, Mason said, although he thinks it's too early to say for sure.
"I was hoping our result was going to be different. I still feel like nanoflares are an important driver of coronal heating," Mason said. "But the evidence from our paper suggests the opposite. I'm a scientist. I have to go where the evidence is pointing."
Peak pandemic times
The effort began at the height of the COVID-19 pandemic.
In spring 2020, CU Boulder, like most universities around the country, had moved its courses entirely online. Lewandowski, however, faced a predicament: She was teaching a class on hands-on research called "Experimental Physics I" that fall, and she had nothing for her students to do.
"This was peak pandemic times," Lewandowski said. "It's sometimes hard to remember back to what life was like then. These students were very isolated. They were really stressed."
Mason, who was then a researcher at the Laboratory for Atmospheric and Space Physics (LASP) at CU Boulder, offered an idea.
The scientist had long wanted to dig into the mathematics of solar flares. In particular, he had tried examining a dataset of thousands of flares that occurred between 2011 and 2018 and had been spotted by instruments in space. They included the National Oceanic and Atmospheric Administration's Geostationary Operational Environmental Satellite (GOES) series and NASA's Miniature X-ray Solar Spectrometer (MinXSS), a CubeSat mission designed and built at LASP.
The problem: There were just too many flares to examine on his own.
That's when Mason and Lewandowski turned to the students for help.
Mason explained that you can infer details about the behaviour of nanoflares by studying the physics of larger flares, which scientists have observed directly for decades.
To do just that, students split into groups of three or four and picked a normal flare they wanted to analyse over the course of the semester. Then, through a series of lengthy calculations, they added up how much heat could each of these events pour into the sun's corona.
Their calculations painted a clear picture: The sum of the sun's nanoflares likely wouldn't be

powerful enough to heat up its corona to millions of degrees Fahrenheit.

Educational experiences

What is making the corona so hot isn't clear. A competing theory suggests that waves in the sun's magnetic field carry energy from inside the sun to its atmosphere.

But the study's actual findings aren't its only important results. Lewandowski said her students were able to have opportunities that are rare for scientists and engineers so early in their careers -- to learn first-hand about the collaborative and often-messy way that scientific research works in the real world.

"We still hear students talking about this course in the halls," she said. "Our students were able to build a community and support each other at a time that was really tough."

CU Boulder co-authors of the new study include Alexandra Werth, postdoctoral researcher at JILA; Colin West, teaching associate professor in physics; Allison Youngblood, astrophysicist at LASP now at the NASA Goddard Space Flight Centre; Donald Woodraska, data systems team lead at LASP; and Courtney Peck, data systems software engineer at LASP and the Cooperative Institute for Research in Environmental Sciences (CIRES).

Funding for the research came from NASA through the MinXSS mission and the U.S. National Science Foundation through the STROBE Science & Technology Centre and JILA Physics Frontier Centre.

- ❖ Galactic bubbles are more complex than imagined

Fresh look at old data reveals novel details about galactic formation

Date: May 8, 2023
Source: Ohio State University

New observations reveal greater details about the two mysterious orbs of gas that tower over the Milky Way's centre. Credit: Pixabay

Astronomers have revealed new evidence about the properties of the giant bubbles of high-energy gas that extend far above and below the Milky Way galaxy's centre.

In a study recently published in*Nature Astronomy*, a team led by scientists at The Ohio State University was able to show that the shells of these structures -- dubbed "eRosita bubbles" after being found by the eRosita X-ray telescope -are more complex than previously thought.

Although they bear a striking similarity in shape to Fermi bubbles, eRosita bubbles are larger and more energetic than their counterparts. Known together as the "galactic bubbles" due to their size and location, they provide an exciting opportunity to study star formation history as well as reveal new clues about how the Milky Way came to be, said Anjali Gupta, lead author of the study and a former postdoctoral researcher at Ohio State who is now a professor of astronomy at Columbus State Community College.

These bubbles exist in the gas that surrounds galaxies, an area which is called the circumgalactic medium.

"Our goal was really to learn more about the circumgalactic medium, a place very important in understanding how our galaxy formed and evolved," Gupta said. "A lot of the regions that we were studying happened to be in the region of the bubbles, so we wanted to see how different the bubbles are when compared to the regions which are away from the bubble."

Previous studies had assumed that these bubbles were heated by the shock of gas as it blows outward from the galaxy, but this paper's main findings suggest the temperature of the gas within the bubbles isn't significantly different from the area outside of it.

"We were surprised to find that the temperature of the bubble region and out of the bubble region were the same," said Gupta.

Additionally, the study demonstrates that these bubbles are so bright because they're filled with extremely dense gas, not because they are at hotter temperatures than the surrounding environment.

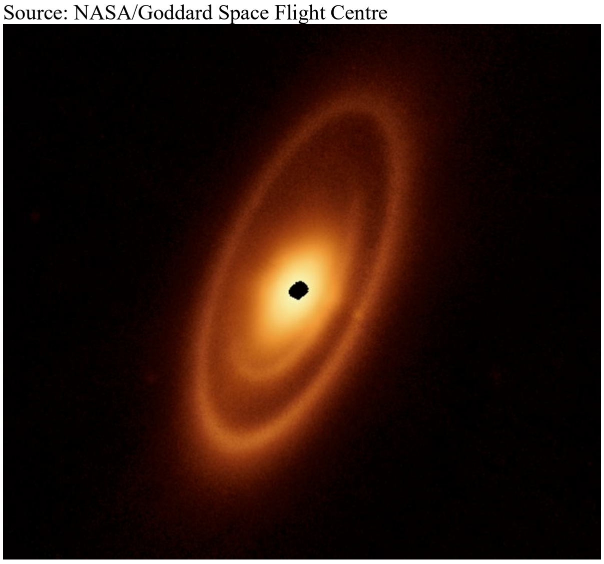
Gupta and Smita Mathur, co-author of the study and a professor of astronomy at Ohio State, did their analysis using observations made by the Suzaku satellite, a collaborative mission between NASA and the Japanese Aerospace Exploration Agency.

By analysing 230 archival observations made between 2005 and 2014, researchers were able to characterize the diffuse emission -- the

electromagnetic radiation from very low-density gas -- of the galactic bubbles, as well as the other hot gases that surround them. Although the origin of these bubbles has been debated in scientific literature, this study is the first that begins to settle it, said Mathur. As the team found an abundance of non-solar neon-oxygen and magnesium-oxygen ratios in the shells, their results strongly suggest that galactic bubbles were originally formed by nuclear star-forming activity, or the injection of energy by massive stars and other kinds of astrophysical phenomena, rather than through the activities of a supermassive black hole.
"Our data supports the theory that these bubbles are most likely formed due to intense star formation activity at the galactic centre, as opposed to black hole activity occurring at the galactic centre," Mathur said. To further investigate the implications their discovery may have for other aspects of astronomy, the team hopes to use new data from other upcoming space missions to continue characterizing the properties of these bubbles, as well as work on novel ways to analyse the data they already have.
"Scientists really do need to understand the formation of the bubble structure, so by using different techniques to better our models, we'll be able to better constrain the temperature and the emission measures that we are looking for," said Gupta.
Other co-authors were Joshua Kingsbury and Sanskriti Das of Ohio State and Yair Krongold of the National Autonomous University of Mexico. This work was supported by NASA.

- Webb looks for Fomalhaut's asteroid belt and finds much more

Date: May 8, 2023
Source: NASA/Goddard Space Flight Centre



This image of the dusty debris disk surrounding the young star Fomalhaut is from Webb's Mid-Infrared Instrument (MIRI). It reveals three nested belts extending out to 14 billion miles (23 billion kilometres) from the star. The inner belts – which had never been seen before – were revealed by Webb for the first time.
Credits: NASA, ESA, CSA, A. Gáspár (University of Arizona). Image processing: A. Pagan (STScI)
Download the full-resolution image from the Space Telescope Science Institute.

Astronomers used NASA's James Webb Space Telescope to image the warm dust around a nearby young star, Fomalhaut, in order to study the first asteroid belt ever seen outside of our solar system in infrared light. But to their surprise, the dusty structures are much more complex than the asteroid and Kuiper dust belts of our solar system. Overall, there are three nested belts extending out to 14 billion miles (23 billion kilometres) from the star; that's 150 times the distance of Earth from the Sun. The scale of the outermost belt is roughly twice the scale of our solar system's Kuiper Belt of small bodies and cold dust beyond Neptune. The inner belts -- which had never been seen before -- were revealed by Webb for the first time.
The belts encircle the young hot star, which can be seen with the naked eye as the brightest star in the southern constellation Piscis Austrinus. The dusty belts are the debris from collisions of larger bodies, analogous to asteroids and comets, and are frequently described as 'debris disks.' "I would describe Fomalhaut as the archetype of debris disks found elsewhere in our galaxy, because it has components similar to those we have in our own planetary system," said András Gáspár of the University of Arizona in Tucson and lead author of a new paper describing these results. "By looking at the patterns in these rings, we can actually start to make a little sketch of what a planetary system ought to look like -- If we could actually take a deep enough picture to see the suspected planets."
The Hubble Space Telescope and Herschel Space Observatory, as well as the Atacama Large Millimetre/submillimetre Array (ALMA), have previously taken sharp images of the outermost belt. However, none of them found any structure interior to it. The inner belts have been resolved for the first time by Webb in infrared light. "Where Webb really excels is that we're able to physically resolve the thermal glow from dust in those inner regions. So, you can see inner belts that we could never see before," said Schuyler Wolff, another member of the team at the University of Arizona.

Hubble, ALMA, and Webb are tag-teaming to assemble a holistic view of the debris disks around a number of stars. "With Hubble and ALMA, we were able to image a bunch of Kuiper Belt analogues, and we've learned loads about how outer disks form and evolve," said Wolff. "But we need Webb to allow us to image a dozen or so asteroid belts elsewhere. We can learn just as much about the inner warm regions of these disks as Hubble and ALMA taught us about the colder outer regions."

These belts most likely are carved by the gravitational forces produced by unseen planets. Similarly, inside our solar system Jupiter corrals the asteroid belt, the inner edge of the Kuiper Belt is sculpted by Neptune, and the outer edge could be shepherded by as-yet-unseen bodies beyond it. As Webb images more systems, we will learn about the configurations of their planets.

Fomalhaut's dust ring was discovered in 1983 in observations made by NASA's Infrared Astronomical Satellite (IRAS). The existence of the ring has also been inferred from previous and longer-wavelength observations using submillimetre telescopes on Mauna Kea, Hawaii, NASA's Spitzer Space Telescope, and Caltech's Submillimetre Observatory.

"The belts around Fomalhaut are kind of a mystery novel: Where are the planets?" said George Rieke, another team member and U.S. science lead for Webb's Mid-Infrared Instrument (MIRI), which made these observations. "I think it's not a very big leap to say there's probably a really interesting planetary system around the star."

"We definitely didn't expect the more complex structure with the second intermediate belt and then the broader asteroid belt," added Wolff. "That structure is very exciting because any time an astronomer sees a gap and rings in a disk, they say, 'There could be an embedded planet shaping the rings!'"

Webb also imaged what Gáspár dubs "the great dust cloud," which may be evidence for a collision occurring in the outer ring between two protoplanetary bodies. This is a different feature from a suspected planet first seen inside the outer ring by Hubble in 2008. Subsequent Hubble observations showed that by 2014 the object had vanished. A plausible interpretation is that this newly discovered feature, like the earlier one, is an expanding cloud of very fine dust particles from two icy bodies that smashed into each other.

The idea of a protoplanetary disk around a star goes back to the late 1700s when astronomers Immanuel Kant and Pierre-Simon Laplace independently developed the theory that the Sun and planets formed from a rotating gas cloud that collapsed and flattened due to gravity. Debris disks develop later, following the formation of planets and dispersal of the primordial gas in the systems. They show that small bodies like asteroids are colliding catastrophically and pulverizing their surfaces into huge clouds of dust and other debris. Observations of their dust provide unique clues to the structure of an exoplanetary system, reaching down to earth-sized planets and even asteroids, which are much too small to see individually.