South Downs Mercury

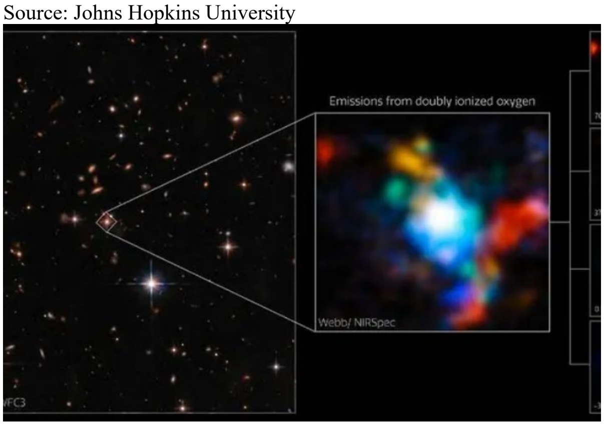
The monthly circular of South Downs Astronomical Society
Issue: 569 – November 4th 2022 Editor: Roger Burgess
Main Speaker Chris Brockley-Blatt, Designing Space Science Instruments
The meeting will also be available via Zoom

Lisa Lacey is standing down as Secretary by the end of August, we need a replacement to take over from her before she stands down

- Unprecedented glimpse of merging galaxies

Swirling galaxies unite around red quasar in 'monster' black hole

Date: October 20, 2022
Source: Johns Hopkins University



Using the James Webb Space Telescope to look back in time at the early universe, astronomers discovered a surprise: a cluster of galaxies merging together around a rare red quasar within a massive black hole. The findings by Johns Hopkins University and an international team offer an unprecedented opportunity to observe how billions of years ago galaxies coalesced into the modern universe.

"We think something dramatic is about to happen in these systems," said co-author Andrey Vayner, a Johns Hopkins postdoctoral fellow who studies the evolution of galaxies. "The galaxy is at this perfect moment in its lifetime, about to transform and look entirely different in a few billion years."

The work is in press in *Astrophysical Journal Letters* and available today on the arXiv paper repository.

The James Webb Space Telescope, launched last December by NASA, the European Space Agency, and the Canadian Space Agency, is the largest, most powerful telescope ever sent into space. Its initial general observations were revealed in July, but this quasar imagery is one of just 13 "early look" projects selected through a highly competitive global competition to decide where the telescope is pointed during its first months of operation.

In Baltimore, the Johns Hopkins team heard their chosen target would be observed within days of President Biden's unveiling of the Webb's debut pictures on July 11, so stayed close to their computers. That following summer Saturday, Vayner and graduate student Yuzo Ishikawa were repeatedly refreshing the Webb database when suddenly the data arrived, leading to a hastily assembled multinational team confab on Sunday to try to make sense of the jaw-droppingly detailed raw images.

Although earlier observations of this area by NASA/ESA Hubble Space Telescope and the Near-Infrared Integral Field Spectrometer instrument on the Gemini-North telescope pinpointed the quasar and hinted at the possibility of a galaxy in transition, no one suspected that with Webb's crisp imaging they'd see multiple galaxies, at least three, swirling the region.

"With previous images we thought we saw hints that the galaxy was possibly interacting with other galaxies on the path to merger because their shapes get distorted in the process and we thought we maybe saw that," said co-principal investigator Nadia L. Zakamska, a Johns Hopkins astrophysicist who helped conceive the project back in 2017 with then-Johns Hopkins postdoc Dominika Wylezalek, who's now the group leader at the University of Heidelberg. "But after we got the Webb data, I was like, 'I have no idea what we're even looking at here, what is all this stuff!' We spent several weeks just staring and staring at these images."

The Webb revealed at least three galaxies moving incredibly fast, suggesting a large amount of mass is present. The team believes this could be one of the densest known areas of galaxy formation in the early universe. Because light takes time to travel to us, when we look at objects like this one in the very distant regions of the universe, we're seeing light that was emitted about 11.5 billion years ago, or from the earliest stages of the universe's evolution. Massive galaxy swarms like this one were likely common then, Zakamska said.

"It's super exciting to be one of the first people to see this really cool object," said Ishikawa, who contributed to the interpretation of the galaxy swarm.

Even Vayner, who'd dreamed of using Webb data since he first heard about the telescope as an undergraduate more than a decade ago, and thought he knew what to expect, was shocked to see his long-studied spot in the universe revealed with such clarity.

"It really will transform our understanding of this object," said Vayner, who was instrumental in adapting the raw Webb data for scientific analysis.

The blindingly bright quasar, fuelled by what Zakamska calls a "monster" black hole at the centre of the galactic swirl, is a rare "extremely red" quasar, about 11.5 billion years old and one of the most powerful ever seen from such distance. It's essentially a black hole in formation, Vayner said, eating the gas around it and growing in mass. The clouds of dust and gas between Earth and the glowing gas near the black hole make the quasar appear red.

The team is already working on follow-up observations into this unexpected galaxy cluster, hoping to better understand how dense, chaotic galaxy clusters form, and how it is affected by supermassive black hole at its heart.

"What you see here is only a small subset of what's in the data set," Zakamska said. "There's just too much going on here so we first highlighted what really is the biggest surprise. Every blob here is a baby galaxy merging into this mommy galaxy and the colours are different velocities and the whole thing is moving in an extremely complicated way. We can now start to untangle the motions."

Other authors include: Wylezalek, Caroline Bertemes, Weizhe Liu, Jorge K. Barrera-Ballesteros, Hsiao-Wen Chen, Andy D. Goulding, Jenny E. Greene, Kevin N. Hainline, Nora Lutzgendorf, Fred Hamann, Timothy Heckman, Sean D. Johnson, Dieter Lutz, Vincenzo Mainieri, Roberto Maiolino, Nicole P. H. Nesvadba, Patrick Ogle, and Eckhard Sturm.

- NASA's Webb takes star-filled portrait of pillars of creation

Date: October 19, 2022
Source: NASA/Goddard Space Flight Centre

The Pillars of Creation are set off in a kaleidoscope of colour in NASA's James Webb Space Telescope's near-infrared-light view. The pillars look like arches and spires rising out of a desert landscape, but are filled with semi-transparent gas and dust, and ever changing. This is a region where young stars are forming – or have barely burst from their dusty cocoons as they continue to form. Credits: NASA, ESA, CSA, STScI; Joseph DePasquale (STScI), Anton M. Koekemoer (STScI), Alyssa Pagan (STScI).
Download the full-resolution, uncompressed version and supporting visuals from the Space Telescope Science Institute.

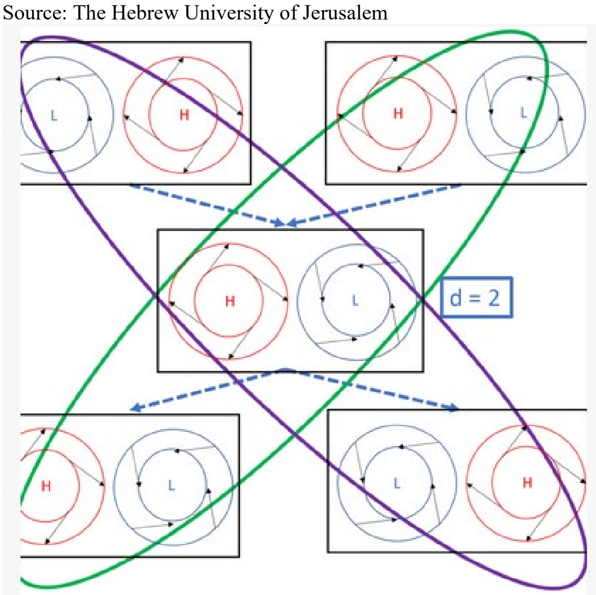
NASA's James Webb Space Telescope has captured a lush, highly detailed landscape -- the iconic Pillars of Creation -- where new stars are forming within dense clouds of gas and dust. The three-dimensional pillars look like majestic rock formations, but are far more permeable. These columns are made up of cool interstellar gas and dust that appear -- at times -- semi-transparent in near-infrared light.

Webb's new view of the Pillars of Creation, which were first made famous when imaged by NASA's Hubble Space Telescope in 1995,

will help researchers revamp their models of star formation by identifying far more precise counts of newly formed stars, along with the quantities of gas and dust in the region. Over time, they will begin to build a clearer understanding of how stars form and burst out of these dusty clouds over millions of years.
Newly formed stars are the scene-stealers in this image from Webb's Near-Infrared Camera (NIRCam). These are the bright red orbs that typically have diffraction spikes and lie outside one of the dusty pillars. When knots with sufficient mass form within the pillars of gas and dust, they begin to collapse under their own gravity, slowly heat up, and eventually form new stars.
What about those wavy lines that look like lava at the edges of some pillars? These are ejections from stars that are still forming within the gas and dust. Young stars periodically shoot out supersonic jets that collide with clouds of material, like these thick pillars. This sometimes also results in bow shocks, which can form wavy patterns like a boat does as it moves through water. The crimson glow comes from the energetic hydrogen molecules that result from jets and shocks. This is evident in the second and third pillars from the top -- the NIRCam image is practically pulsing with their activity. These young stars are estimated to be only a few hundred thousand years old.
Although it may appear that near-infrared light has allowed Webb to "pierce through" the clouds to reveal great cosmic distances beyond the pillars, there are no galaxies in this view. Instead, a mix of translucent gas and dust known as the interstellar medium in the densest part of our Milky Way galaxy's disk blocks our view of the deeper universe.
This scene was first imaged by Hubble in 1995 and revisited in 2014, but many other observatories have also stared deeply at this region. Each advanced instrument offers researchers new details about this region, which is practically overflowing with stars.
This tightly cropped image is set within the vast Eagle Nebula, which lies 6,500 light-years away.
The James Webb Space Telescope is the world's premier space science observatory. Webb will solve mysteries in our solar system, look beyond to distant worlds around other stars, and probe the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and CSA (Canadian Space Agency).

- ❖ Looking to move to a galaxy far, far away? Innovative system evaluates habitability of distant planets

Computerized system classifies atmospheres of planets and identifies those suitable for future human settlements
Date: October 20, 2022
Source: The Hebrew University of Jerusalem



The climate crisis presents a huge challenge to all people on Earth. It has led many scientists to look for exoplanets, planets outside our solar system that humans could potentially settle.
The James Webb Space Telescope was developed as part of this search to provide detailed observational data about Earth-like exoplanets in the coming years. A new project, led by Dr. Assaf Hochman at the Fredy & Nadine Herrmann Institute of Earth Sciences at the Hebrew University of Jerusalem (HU), in collaboration with Dr. Paolo De Luca at the Barcelona Supercomputing Centre and Dr. Thaddeus D. Komacek at the University of Maryland, has successfully developed a framework to study the atmospheres of distant planets and locate those planets fit for human habitation, without having to visit them physically. Their joint research study was published in the *Astrophysical Journal*.
Classifying climate conditions and measuring climate sensitivity are central elements when assessing the viability of exoplanets as potential candidates for human habitation. In the current study, the research team examined TRAPPIST-1e, a planet located some 40 light years from the Earth and scheduled to be

documented by the James Webb Space Telescope in the coming year. The researchers looked at the sensitivity of the planet's climate to increases in greenhouse gases and compared it with conditions on Earth. Using a computerized simulation of the climate on TRAPPIST-1e, they could assess the impact of changes in greenhouse gas concentration. The study focused on the effect of an increase in carbon dioxide on extreme weather conditions, and on the rate of changes in weather on the planet. "These two variables are crucial for the existence of life on other planets, and they are now being studied in depth for the first time in history," explained Hochman.

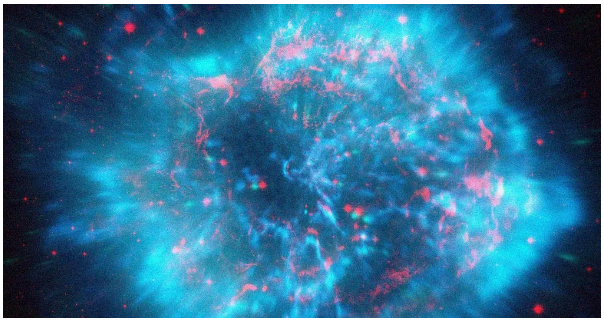
According to the research team, studying the climate variability of earth-like exoplanets provides a better understanding of the climate changes we are currently experiencing on Earth. Additionally, this kind of research offers a new understanding of how planet Earth's atmosphere might change in the future.

Hochman and his research partners found that planet TRAPPIST-1e has a significantly more sensitive atmosphere than planet Earth. They estimate that an increase in greenhouse gases there could lead to more extreme climate changes than we would experience here on Earth because one side of TRAPPIST-1e constantly faces its own sun, in the same way, that our moon always has one side facing the Earth.

As Hochman concluded, "the research framework we developed, along with observational data from the Webb Space Telescope, will enable scientists to efficiently assess the atmospheres of many other planets without having to send a space crew to visit them physically. This will help us make informed decisions in the future about which planets are good candidates for human settlement and perhaps even to find life on those planets."

- The most precise accounting yet of dark energy and dark matter

Date: October 19, 2022
Source: Harvard-Smithsonian Centre for Astrophysics



Astrophysicists have performed a powerful new analysis that places the most precise limits yet on the composition and evolution of the universe. With this analysis, dubbed Pantheon+, cosmologists find themselves at a crossroads.

Pantheon+ convincingly finds that the cosmos is composed of about two-thirds dark energy and one-third matter -- mostly in the form of dark matter -- and is expanding at an accelerating pace over the last several billion years. However, Pantheon+ also cements a major disagreement over the pace of that expansion that has yet to be solved.

By putting prevailing modern cosmological theories, known as the Standard Model of Cosmology, on even firmer evidentiary and statistical footing, Pantheon+ further closes the door on alternative frameworks accounting for dark energy and dark matter. Both are bedrocks of the Standard Model of Cosmology but have yet to be directly detected and rank among the model's biggest mysteries. Following through on the results of Pantheon+, researchers can now pursue more precise observational tests and hone explanations for the ostensible cosmos.

"With these Pantheon+ results, we are able to put the most precise constraints on the dynamics and history of the universe to date," says Dillon Brout, an Einstein Fellow at the Centre for Astrophysics | Harvard & Smithsonian. "We've combed over the data and can now say with more confidence than ever before how the universe has evolved over the eons and that the current best theories for dark energy and dark matter hold strong."

Brout is the lead author of a series of papers describing the new Pantheon+ analysis, published jointly today in a special issue of *The Astrophysical Journal*.

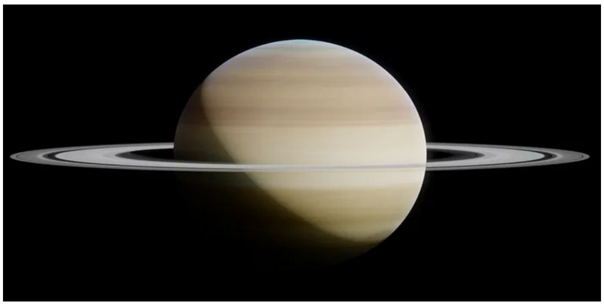
Pantheon+ is based on the largest dataset of its kind, comprising more than 1,500 stellar explosions called Type Ia supernovae. These bright blasts occur when white dwarf stars -- remnants of stars like our Sun -- accumulate too much mass and undergo a runaway

thermonuclear reaction. Because Type Ia supernovae outshine entire galaxies, the stellar detonations can be glimpsed at distances exceeding 10 billion light years, or back through about three-quarters of the universe's total age. Given that the supernovae blaze with nearly uniform intrinsic brightness's, scientists can use the explosions' apparent brightness, which diminishes with distance, along with redshift measurements as markers of time and space. That information, in turn, reveals how fast the universe expands during different epochs, which is then used to test theories of the fundamental components of the universe.
The breakthrough discovery in 1998 of the universe's accelerating growth was thanks to a study of Type Ia supernovae in this manner. Scientists attribute the expansion to an invisible energy, therefore monikered dark energy, inherent to the fabric of the universe itself. Subsequent decades of work have continued to compile ever-larger datasets, revealing supernovae across an even wider range of space and time, and Pantheon+ has now brought them together into the most statistically robust analysis to date.
"In many ways, this latest Pantheon+ analysis is a culmination of more than two decades' worth of diligent efforts by observers and theorists worldwide in deciphering the essence of the cosmos," says Adam Riess, one of the winners of the 2011 Nobel Prize in Physics for the discovery of the accelerating expansion of the universe and the Bloomberg Distinguished Professor at Johns Hopkins University (JHU) and the Space Telescope Science Institute in Baltimore, Maryland. Riess is also an alum of Harvard University, holding a PhD in astrophysics.
Brout's own career in cosmology traces back to his undergraduate years at JHU, where he was taught and advised by Riess. There Brout worked with then-PhD-student and Riess-advisee Dan Scolnic, who is now an assistant professor of physics at Duke University and another co-author on the new series of papers. Several years ago, Scolnic developed the original Pantheon analysis of approximately 1,000 supernovae.
Now, Brout and Scolnic and their new Pantheon+ team have added some 50 percent more supernovae data points in Pantheon+, coupled with improvements in analysis techniques and addressing potential sources of error, which ultimately has yielded twice the precision of the original Pantheon.
"This leap in both the dataset quality and in our understanding of the physics that underpin it would not have been possible without a stellar team of students and collaborators working diligently to improve every facet of the analysis," says Brout.
Taking the data as a whole, the new analysis holds that 66.2 percent of the universe manifests as dark energy, with the remaining 33.8 percent being a combination of dark matter and matter. To arrive at even more comprehensive understanding of the constituent components of the universe at different epochs, Brout and colleagues combined Pantheon+ with other strongly evidenced, independent and complementary measures of the large-scale structure of the universe and with measurements from the earliest light in the universe, the cosmic microwave background.
Another key Pantheon+ result relates to one of the paramount goals of modern cosmology: nailing down the current expansion rate of the universe, known as the Hubble constant. Pooling the Pantheon+ sample with data from the SH0ES (Supernova H0 for the Equation of State) collaboration, led by Riess, results in the most stringent local measurement of the current expansion rate of the universe. Pantheon+ and SH0ES together find a Hubble constant of 73.4 kilometres per second per megaparsec with only 1.3% uncertainty. Stated another way, for every megaparsec, or 3.26 million light years, the analysis estimates that in the nearby universe, space itself is expanding at more than *160,000 miles per hour*.
However, observations from an entirely different epoch of the universe's history predict a different story. Measurements of the universe's earliest light, the cosmic microwave background, when combined with the current Standard Model of Cosmology, consistently peg the Hubble constant at a rate that is significantly less than observations taken via Type Ia supernovae and other astrophysical markers. This sizable discrepancy between the two methodologies has been termed the Hubble tension.
The new Pantheon+ and SH0ES datasets heighten this Hubble tension. In fact, the tension has now passed the important 5-sigma threshold (about one-in-a-million odds of arising due to random chance) that physicists

use to distinguish between possible statistical flukes and something that must accordingly be understood. Reaching this new statistical level highlights the challenge for both theorists and astrophysicists to try and explain the Hubble constant discrepancy.
"We thought it would be possible to find clues to a novel solution to these problems in our dataset, but instead we're finding that our data rules out many of these options and that the profound discrepancies remain as stubborn as ever," says Brout.
The Pantheon+ results could help point to where the solution to the Hubble tension lies. "Many recent theories have begun pointing to exotic new physics in the very early universe, however such unverified theories must withstand the scientific process and the Hubble tension continues to be a major challenge," says Brout.
Overall, Pantheon+ offers scientists a comprehensive lookback through much of cosmic history. The earliest, most distant supernovae in the dataset gleam forth from 10.7 billion light years away, meaning from when the universe was roughly a quarter of its current age. In that earlier era, dark matter and its associated gravity held the universe's expansion rate in check. Such state of affairs changed dramatically over the next several billion years as the influence of dark energy overwhelmed that of dark matter. Dark energy has since flung the contents of the cosmos ever-farther apart and at an ever-increasing rate.
"With this combined Pantheon+ dataset, we get a precise view of the universe from the time when it was dominated by dark matter to when the universe became dominated by dark energy," says Brout. "This dataset is a unique opportunity to see dark energy turn on and drive the evolution of the cosmos on the grandest scales up through present time."
Studying this changeover now with even stronger statistical evidence will hopefully lead to new insights into dark energy's enigmatic nature.
"Pantheon+ is giving us our best chance to date of constraining dark energy, its origins, and its evolution," says Brout.

- Scientists compile Cassini's unique observations of Saturn's rings

Compilation will inform future investigations into the formation, evolution of ring system
Date: October 18, 2022
Source: Southwest Research Institute

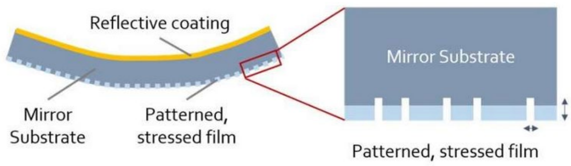


Southwest Research Institute scientists have compiled 41 solar occultation observations of Saturn's rings from the Cassini mission. The compilation, published recently in the scientific journal Icarus, will inform future investigations of the particle size distribution and composition of Saturn's rings, key elements to understanding their formation and evolution.
"For nearly two decades, NASA's Cassini spacecraft shared the wonders of Saturn and its family of icy moons and signature rings, but we still don't definitively know the origins of the ring system," said Dr. Stephanie Jarmak, a researcher in the SwRI Space Science Division. "Evidence indicates that the rings are relatively young and could have formed from the destruction of an icy satellite or a comet. However, to support any one origin theory, we need to have a good idea of the size of particles making up the rings."
Cassini's Ultraviolet Imaging Spectrograph (UVIS) was uniquely sensitive to some of the smallest ring particles, particularly with the observations it made in the extreme ultraviolet wavelength.
To determine the size of the ring particles, UVIS observed them when the instrument was pointed at the Sun, looking through the rings in what is known as a solar occultation. Ring particles partially blocked the path of the light, providing a direct measurement of the optical depth, a key parameter for determining the size and composition of the ring particles.
"Given the wavelength of the light coming from the Sun, these observations gave us insight into the smallest particle sizes with Saturn's rings," Jarmak said. "UVIS can detect dust particles at the micron level, helping us understand the origin, collisional activity and destruction of the ring particles within the system."
The compilation also delves into the variations in the optical depth of occultation observations, which can help determine particle size and composition. During an occultation, light emitted by a background source, such as the Sun, is absorbed and

scattered by the particles in the light's path. The amount of light blocked by ring particles provides a direct measurement of the ring optical depth.
Including optical depth is vital to understanding the structure of the rings. The research measured the optical depth as a function of the viewing geometry, which refers to the observation angles of the ring system with respect to the Cassini spacecraft. As light passing through the ring's changes at various angles, scientists can form a picture of the rings' structures.
"Ring systems around giant planets also provide test beds for investigating fundamental physical properties and processes in our solar system in general," Jarmak said. "These particles are thought to result from objects colliding and forming in a disk and building up larger particles. Understanding how they form these ring systems could help us understand how planets form as well."

- New way to make telescope mirrors could sharpen our view of the universe

Femtosecond lasers used to fabricate precision ultrathin mirrors for space telescopes that capture star formation and other high-energy space events
Date: October 20, 2022
Source: Optica



Researchers developed a new way to use femtosecond laser pulses to fabricate the high-precisio...

Researchers have developed a new way to use femtosecond laser pulses to fabricate the high-precision ultrathin mirrors required for high-performance x-ray telescopes. The technique could help improve the space-based x-ray telescopes used to capture high-energy cosmic events involved in forming new stars and supermassive black holes.
"Detecting cosmic x-rays is a crucial piece of our exploration of the universe that unveils the high-energy events that permeate our universe but are not observable in other wavebands," said research team leader Heng Zuo, who performed the research at MIT Kavli Institute for Astrophysics and Space Research and is now at the University of New Mexico. "The technologies our group developed will help telescopes obtain sharp images of astronomical x-rays that can answer many intriguing science questions."
X-ray telescopes orbit above the Earth's atmosphere and contain thousands of thin mirrors that must each have a precisely curved shape and be carefully aligned with respect to all the other mirrors. In *Optica*, Optica Publishing Group's journal for high-impact research, the researchers describe how they used femtosecond laser micromachining to bend these ultrathin mirrors into a precise shape and correct errors that can arise in the fabrication process.
"It is difficult to make ultra-thin mirrors with an exact shape because the fabrication process tends to severely bend the thin material," said Zuo. "Also, telescope mirrors are usually coated to increase reflectivity, and these coatings typically deform the mirrors further. Our techniques can address both challenges."

Precision bending

New ways to fabricate ultra-precise and high-performance x-ray mirrors for telescopes are needed as new mission concepts continue to push the limits of x-ray imaging. For example, NASA's Lynx X-ray Surveyor concept will have the most powerful x-ray optic ever conceived and will require the manufacture of a large number of ultra-high-resolution mirrors.
To meet this need, Zuo's research group combined femtosecond laser micromachining with a previously developed technique called stress-based figure correction. Stress-based figure correction exploits the bendability of thin mirrors by applying a deformable film to the mirror substrate to adjust its stress states and induce controlled bending.
The technique involves selectively removing regions of a stressed film grown onto the back surface of a flat mirror. The researchers selected femtosecond lasers to accomplish this because the pulses produced by these lasers can create extremely precise holes, channels and marks with little collateral damage. Also, the high repetition rates of these lasers allow faster machining speeds and throughput compared to traditional methods. This could help speed up fabrication for the large numbers of ultra-thin mirrors required for next-generation x-ray telescopes.

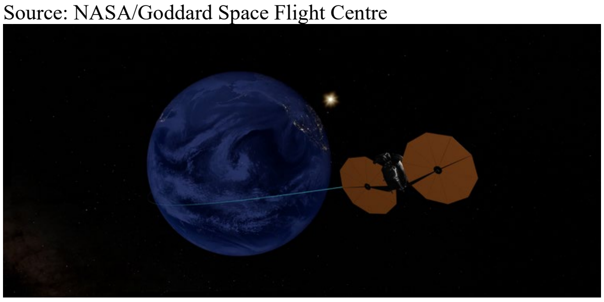
Mapping stress

To carry out the new approach the researchers first had to determine exactly how laser micromachining changes the mirror's surface curvature and stress states. Then they

measured the initial mirror shape and created a map of the stress correction necessary to create the desired shape. They also developed a multi-pass correction scheme that uses a feedback loop to repeatedly reduce errors until an acceptable mirror profile is achieved.
"Our experimental results showed that patterned removal of periodic holes leads to equibiaxial (bowl-shaped) stress states, while fine-pitched oriented removal of periodic troughs generates non-equibiaxial (potato-chip-shaped) stress components," said Zuo. "Combining these two features with proper rotation of the trough orientation we can create a variety of stress states that can, in principle, be used to correct for any type of error in the mirrors."
In this work, the researchers demonstrated the new technique on flat silicon wafers using regular patterns. To correct real x-ray astronomy telescope mirrors, which are curved in two directions, the researchers are developing a more complex optical setup for 3D movement of the substrates.

- NASA's Lucy to fly past thousands of objects for Earth gravity assist

Date: October 14, 2022
Source: NASA/Goddard Space Flight Centre

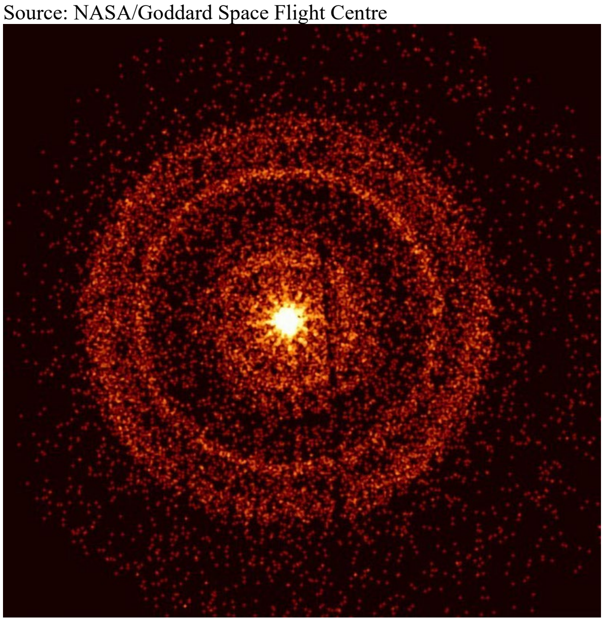


Mission engineers will track NASA's Lucy spacecraft nonstop as it prepares to swoop near Earth on Oct. 16 to use this planet's gravity to set itself on a course toward the Jupiter Trojan asteroids.
But they also will be closely tracking something else: more than 47,000 satellites, debris, and other objects circling our planet. A greater than 1-10,000 chance that Lucy will collide with one of these objects will require mission engineers to slightly adjust the spacecraft's trajectory.
Although an adjustment is unlikely, and collisions are rare, the chances are increasing as the number of objects in Earth's orbit grows, NASA experts say.
The International Space Station, for instance, has maneuverer out of the way of space debris 31 times since 1999, including three times since 2020.
"Low-Earth orbit is getting more crowded, so that has to be part of the consideration nowadays, especially for missions that fly low, like Lucy," said Dr. Dolan Highsmith, chief engineer for the Conjunction Assessment Risk Analysis group at NASA's Goddard Space Flight Centre in Greenbelt, Maryland. The group determines the probabilities of collisions between NASA's robotic spacecraft and Earth-orbiting objects. NASA's Johnson Space Centre in Houston does the same for crewed spacecraft, such as the space station.
Launched on Oct. 16, 2021, Lucy is on a 12-year-journey to study multiple Trojan asteroids up close. It'll be the first spacecraft to visit these remnants from the early solar system, helping scientists hone their theories on how the planets formed 4.5 billion years ago and why they ended up in their current configuration.
But Lucy has a long way to go before it arrives at the Trojans in 2027. The upcoming gravity assist is one of three the spacecraft will rely on to catapult itself to its deep-space targets.
When Lucy comes nearest to Earth for its first gravity assist it will cruise 220 miles (350 km) above the surface. That's lower than the altitude of the space station and low enough that the spacecraft will be visible with the naked eye from western Australia for a few minutes starting at 6:55 p.m. local time (10:55 UTC). On its way down, Lucy will fly through the most crowded layer of Earth's orbit, which is monitored by the U.S. Space Force's 18th Space Control Squadron. The squadron helps NASA identify close approaches.
Engineers began collision analysis for Lucy a week before the spacecraft's Earth approach. Starting the process any earlier would render collision predictions futile, Highsmith said: "The further you're predicting into the future, the more uncertain you are about where an object is going to be."
Determining the positions of spacecraft, plus orbiting satellites and debris, is challenging, particularly when trying to anticipate the future. Largely that's because the Sun plays a major role in pulling or pushing objects around, and future solar activity is hard to predict. For example, the Sun's activity -- how much plasma and radiation it shoots out -- affects atmosphere density, and thus how

much friction will tug on a spacecraft and slow it down.
So, the closer the collision assessment is to the Earth flyby time, the better. NASA sends Lucy's whereabouts to the Space Force squadron daily. If the squadron determines that Lucy could intersect with something, Highsmith's group will calculate the probability of a collision and work with the mission team to move the spacecraft, if necessary.
With such a high value mission, you really need to make sure that you have the capability, in case it's a bad day, to get out of the way," Highsmith said.
Lucy navigation engineers have two manoeuvre options ready in case the spacecraft needs to avoid an object. Both manoeuvres require engine burns to speed up the spacecraft, which is traveling about 8 miles (12 km) per second. Each manoeuvre can move Lucy's closest approach to Earth up by 2 seconds or 4 seconds, respectively.
"That's enough to avoid any one thing that could be in the way," said Kevin E. Berry, Lucy's flight dynamics team lead from NASA Goddard.

- NASA's Swift, Fermi missions detect exceptional cosmic blast

Date: October 14, 2022
Source: NASA/Goddard Space Flight Centre



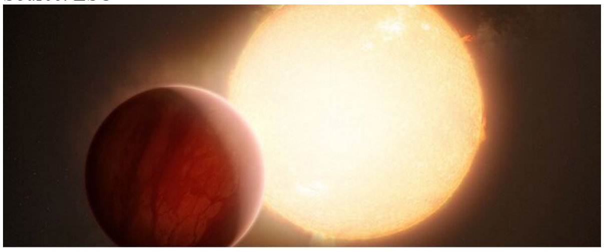
Swift's X-Ray Telescope captured the afterglow of GRB 221009A about an hour after it was first detected. The bright rings form as a result of X-rays scattered from otherwise unobservable dust layers within our galaxy that lie in the direction of the burst.
Credits: Credit: NASA/Swift/A. Beardmore (University of Leicester)
Download high-resolution video and images from NASA's Scientific Visualization Studio

Astronomers around the world are captivated by an unusually bright and long-lasting pulse of high-energy radiation that swept over Earth Sunday, Oct. 9. The emission came from a gamma-ray burst (GRB) -- the most powerful class of explosions in the universe -- that ranks among the most luminous events known.
On Sunday morning Eastern time, a wave of X-rays and gamma rays passed through the solar system, triggering detectors aboard NASA's Fermi Gamma-ray Space Telescope, Neil Gehrels Swift Observatory, and Wind spacecraft, as well as others. Telescopes around the world turned to the site to study the aftermath, and new observations continue.
Called GRB 221009A, the explosion provided an unexpectedly exciting start to the 10th Fermi Symposium, a gathering of gamma-ray astronomers now underway in Johannesburg, South Africa. "It's safe to say this meeting really kicked off with a bang -- everyone's talking about this," said Judy Racusin, a Fermi deputy project scientist at NASA's Goddard Space Flight Centre in Greenbelt, Maryland, who is attending the conference.
The signal, originating from the direction of the constellation Sagitta, had travelled an estimated 1.9 billion years to reach Earth. Astronomers think it represents the birth cry of a new black hole, one that formed in the heart of a massive star collapsing under its own weight. In these circumstances, a nascent black hole drives powerful jets of particles traveling near the speed of light. The jets pierce through the star, emitting X-rays and gamma rays as they stream into space.
The light from this ancient explosion brings with it new insights into stellar collapse, the birth of a black hole, the behaviour and interaction of matter near the speed of light, the conditions in a distant galaxy -- and much more. Another GRB this bright may not appear for decades.
According to a preliminary analysis, Fermi's Large Area Telescope (LAT) detected the burst for more than 10 hours. One reason for the burst's brightness and longevity is that, for a GRB, it lies relatively close to us.
"This burst is much closer than typical GRBs, which is exciting because it allows us to detect many details that otherwise would be too faint to see," said Roberta Pillera, a Fermi LAT Collaboration member who led initial communications about the burst and a doctoral student at the Polytechnic University of Bari, Italy. "But it's also among the most energetic and luminous bursts ever seen

regardless of distance, making it doubly exciting."
The burst also provided a long-awaited inaugural observing opportunity for a link between two experiments on the International Space Station -- NASA's NICER X-ray telescope and a Japanese detector called the Monitor of All-sky X-ray Image (MAXI). Activated in April, the connection is dubbed the Orbiting High-energy Monitor Alert Network (OHMAN). It allows NICER to rapidly turn to outbursts detected by MAXI, actions that previously required intervention by scientists on the ground.
"OHMAN provided an automated alert that enabled NICER to follow up within three hours, as soon as the source became visible to the telescope," said Zaven Arzoumanian, the NICER science lead at Goddard. "Future opportunities could result in response times of a few minutes."

- Heaviest element yet detected in an exoplanet atmosphere

Date: October 13, 2022
Source: ESO

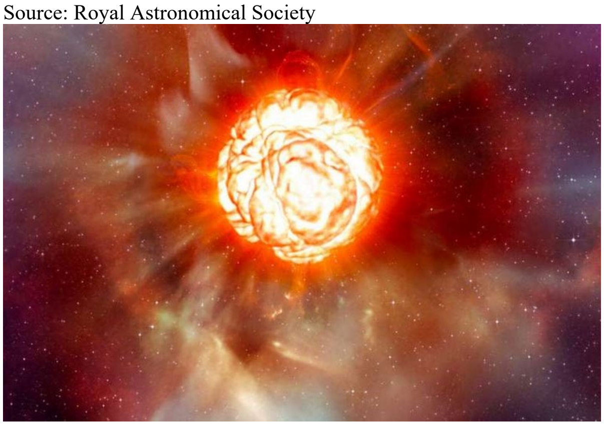


Using the European Southern Observatory's Very Large Telescope (ESO's VLT), astronomers have discovered the heaviest element ever found in an exoplanet atmosphere -- barium. They were surprised to discover barium at high altitudes in the atmospheres of the ultra-hot gas giants WASP-76 b and WASP-121 b -- two exoplanets, planets which orbit stars outside our Solar System. This unexpected discovery raises questions about what these exotic atmospheres may be like.
"The puzzling and counterintuitive part is: why is there such a heavy element in the upper layers of the atmosphere of these planets?" says Tomás Azevedo Silva, a PhD student at the University of Porto and the Instituto de Astrofísica e Ciências do Espaço (IA) in Portugal who led the study published today in Astronomy & Astrophysics.
WASP-76 b and WASP-121 b are no ordinary exoplanets. Both are known as ultra-hot Jupiter’s as they are comparable in size to Jupiter whilst having extremely high surface temperatures soaring above 1000°C. This is due to their close proximity to their host stars, which also means an orbit around each star takes only one to two days. This gives these planets rather exotic features; in WASP-76 b, for example, astronomers suspect it rains iron. But even so, the scientists were surprised to find barium, which is 2.5 times heavier than iron, in the upper atmospheres of WASP-76 b and WASP-121 b. "Given the high gravity of the planets, we would expect heavy elements like barium to quickly fall into the lower layers of the atmosphere," explains co-author Olivier Demangeon, a researcher also from the University of Porto and IA.
"This was in a way an 'accidental' discovery," says Azevedo Silva. "We were not expecting or looking for barium in particular and had to cross-check that this was actually coming from the planet since it had never been seen in any exoplanet before."
The fact that barium was detected in the atmospheres of both of these ultra-hot Jupiter’s suggests that this category of planets might be even stranger than previously thought. Although we do occasionally see barium in our own skies, as the brilliant green colour in fireworks, the question for scientists is what natural process could cause this heavy element to be at such high altitudes in these exoplanets. "At the moment, we are not sure what the mechanisms are," explains Demangeon.
In the study of exoplanet atmospheres ultra-hot Jupiter’s are extremely useful. As Demangeon explains: "Being gaseous and hot, their atmospheres are very extended and are thus easier to observe and study than those of smaller or cooler planets."
Determining the composition of an exoplanet's atmosphere requires very specialised equipment. The team used the ESPRESSO instrument on ESO's VLT in Chile to analyse starlight that had been filtered through the atmospheres of WASP-76 b and WASP-121 b. This made it possible to clearly detect several elements in them, including barium.
These new results show that we have only scratched the surface of the mysteries of exoplanets. With future instruments such as the high-resolution ArmazoNes high Dispersion Echelle Spectrograph (ANDES), which will operate on ESO's upcoming Extremely Large Telescope (ELT), astronomers will be able to study the

atmospheres of exoplanets large and small, including those of rocky planets similar to Earth, in much greater depth and to gather more clues as to the nature of these strange worlds.

- Red alert: massive stars sound warning they are about to go supernova

Date: October 13, 2022
Source: Royal Astronomical Society



An artist's impression of Betelgeuse's supernova. Credit: European Southern Observatory/L. Calçada

Astronomers from Liverpool John Moores University and the University of Montpellier have devised an 'early warning' system to sound the alert when a massive star is about to end its life in a supernova explosion. The work was published in *Monthly Notices of the Royal Astronomical Society*.

In this new study, researchers determined that massive stars (typically between 8 and 20 solar masses) in the last phase of their lives, the so-called 'red supergiant' phase, will suddenly become around a hundred times fainter in visible light in the last few months before they die. This dimming is caused by a sudden accumulation of material around the star, which obscures its light.

Until now, it was not known how long it took the star to accrete this material. Now, for the first time, researchers have simulated how red supergiants might look when they are embedded within these pre-explosion 'cocoons'.

Old telescope archives show that images do exist of stars that went on to explode around a year after the image was taken. The stars appear as normal in these images, meaning they cannot yet have built up the theoretical circumstellar cocoon. This suggests that the cocoon is assembled in less than a year, which is considered to be extremely fast.

Benjamin Davies from Liverpool John Moores University, and lead author of the paper, says "The dense material almost completely obscures the star, making it 100 times fainter in the visible part of the spectrum. This means that, the day before the star explodes, you likely wouldn't be able to see it was there." He adds, "Until now, we've only been able to get detailed observations of supernovae hours after they've already happened. With this early-warning system we can get ready to observe them real-time, to point the world's best telescopes at the precursor stars, and watch them getting literally ripped apart in front of our eyes."

- Dust plumes observed being 'pushed' into interstellar space by intense starlight

Date: October 12, 2022
Source: University of Cambridge

Credit: NASA, ESA, CSA, STScI, JPL-Caltech.

The results, made using infrared images of the binary star system WR140 taken over 16 years, are reported in the journal *Nature*.

In a complementary study of WR140, published in *Nature Astronomy,* NASA's James Webb Space Telescope (JWST) was able to see much deeper to snap an image of not just a single accelerating dust plume, but almost 20 of them, nested inside each other like a giant set of onion skins.

WR140 is comprised of a huge Wolf-Rayet star and an even bigger blue supergiant star, gravitationally bound in an eight-year orbit. This binary star, in the Cygnus constellation, has been monitored for two decades with one of the world's largest optical telescopes at the Keck Observatory in Hawaii.

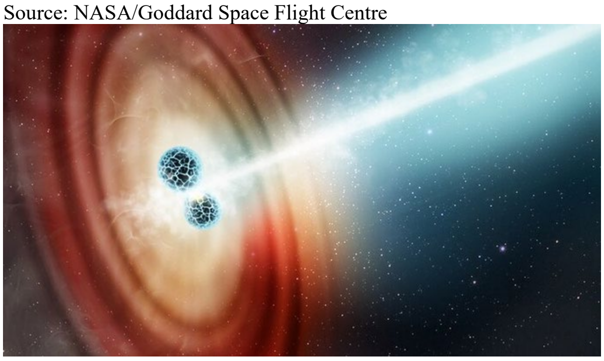
WR140 episodically puffs out plumes of dust stretching thousands of times the distance from the Earth to the Sun. These dust plumes, produced every eight years, give astronomers a unique opportunity to observe how starlight can affect matter.

It's known that light carries momentum, exerting a push on matter known as radiation pressure. Astronomers often witness the outcome of this phenomenon in the form of matter coasting at high speed around the

cosmos, but it's been a difficult process to catch in the act. Direct recording of acceleration due to forces other than gravity is rarely witnessed, and never in a stellar environment like this.
"It's hard to see starlight causing acceleration because the force fades with distance, and other forces quickly take over," said Yinuo Han from Cambridge's Institute of Astronomy, first author of the *Nature* paper. "To witness acceleration at the level that it becomes measurable, the material needs to be reasonably close to the star or the source of the radiation pressure needs to be extra strong. WR140 is a binary star whose ferocious radiation field supercharges these effects, placing them within reach of our high-precision data."
All stars generate stellar winds, but those from Wolf-Rayet stars can be more like a stellar hurricane. Elements such as carbon in the wind condense out as soot, which remains hot enough to glow bright in the infrared. Like smoke in the wind, this gives telescopes something that can be observed.
The team used an imaging technology known as interferometry which was able to act like a zoom lens for the 10-metre Keck telescope mirror, enabling the researchers to recover sufficiently sharp images of WR140 for the study.
Han and his team found that the dust does not stream out from the star with the wind in a hazy ball. Instead, the dust forms where the winds from the two stars collide, on the surface of a cone-shaped shock front between them.
Because the orbiting binary star is in constant motion, the shock front also rotates. The sooty plume gets wrapped into a spiral, in the same way that droplets form a spiral in a garden sprinkler.
The researchers found that WR140 has other tricks up its sleeve. The two stars are not on circular but rather elliptical orbits, and dust production turns on and off as the binary nears and departs the point of closest approach. By modelling these effects into the three-dimensional geometry of the dust plume, the astronomers were able to measure to location of dust features in three-dimensional space.
"Like clockwork, this star puffs out sculpted smoke rings every eight years, with all this wonderful physics written then inflated in the wind like a banner for us to read," said co-author Professor Peter Tuthill from the University of Sydney. "Eight years later as the binary returns in its orbit, another appears the same as the one before, streaming out into space inside the bubble of the previous one, like a set of giant nested Russian dolls."
Because the dust produced by this Wolf-Rayet is so predictable and expands to such large distances, it offered the astronomers a unique laboratory to examine the acceleration zone.
"In the absence of external forces, each dust spiral should expand at a constant speed," said Han, who is also a co-author on the JWST paper. "We were puzzled at first because we could not get our model to fit the observations, until we finally realised that we were seeing something new. The data did not fit because the expansion speed wasn't constant, but rather that it was accelerating. We'd caught that for the first time on camera."
"In one sense, we always knew this must be the reason for the outflow, but I never dreamed we'd be able to see the physics at work like this," said Tuthill. "When I look at the data now, I see WR140's plume unfurling a like giant sail made of dust. When it catches the photon wind streaming from the star, like a yacht catching a gust, it makes a sudden leap forward."
With JWST now in operation, researchers can learn much more about WR140 and similar systems. "The Webb telescope offers new extremes of stability and sensitivity," said Ryan Lau who led the JWST study. "We'll now be able to make observations like this much more easily than from the ground, opening a new window into the world of Wolf-Rayet physics."
The research was funded in part by the Gates Cambridge Trust.

- ❖ Hubble spots ultra-speedy jet blasting from star crash

Titanic stellar collision rattles space and time
Date: October 12, 2022
Source: NASA/Goddard Space Flight Centre



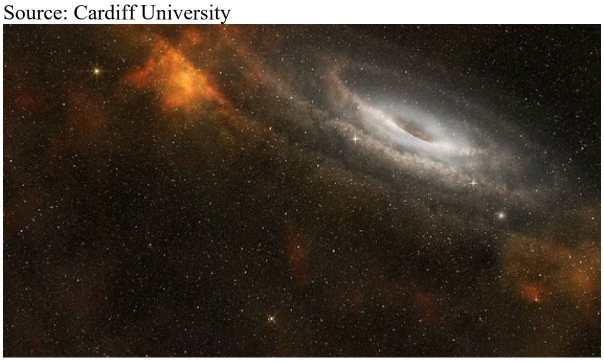
This is an artist's impression of two neutron stars colliding

Astronomers using NASA's Hubble Space Telescope have made a unique measurement that indicates a jet, ploughing through space at speeds greater than 99.97% the speed of light, was propelled by the titanic collision between two neutron stars.
The explosive event, named GW170817, was observed in August 2017. The blast released the energy comparable to that of a supernova explosion. It was the first combined detection of gravitational waves and gamma radiation from a binary neutron star merger.
This was a major watershed in the ongoing investigation of these extraordinary collisions. The aftermath of this merger was collectively seen by 70 observatories around the globe and in space, across a broad swath of the electromagnetic spectrum in addition to the gravitational wave detection. This heralded a significant breakthrough for the emerging field of Time Domain and Multi-Messenger Astrophysics, the use of multiple "messengers" like light and gravitational waves to study the universe as it changes over time.
Scientists quickly aimed Hubble at the site of the explosion just two days later. The neutron stars collapsed into a black hole whose powerful gravity began pulling material toward it. That material formed a rapidly-spinning disk that generated jets moving outward from its poles. The roaring jet smashed into and swept up material in the expanding shell of explosion debris. This included a blob of material through which a jet emerged.
While the event took place in 2017, it has taken several years for scientists to come up with a way to analyse the Hubble data and data from other telescopes to paint this full picture.
The Hubble observation was combined with observations from multiple National Science Foundation radio telescopes working together for very long baseline interferometry (VLBI). The radio data were taken 75 days and 230 days after the explosion.
"I'm amazed that Hubble could give us such a precise measurement, which rivals the precision achieved by powerful radio VLBI telescopes spread across the globe," said Kunal P. Mooley of Caltech in Pasadena, California, lead author of a paper being published in the October 13 journal of *Nature* magazine.
The authors used Hubble data together with data from ESA's (the European Space Agency) Gaia satellite, in addition to VLBI, to achieve extreme precision. "It took months of careful analysis of the data to make this measurement," said Jay Anderson of the Space Telescope Science Institute in Baltimore, Maryland.
By combining the different observations, they were able to pinpoint the explosion site. The Hubble measurement showed the jet was moving at an apparent velocity of seven times the speed of light. The radio observations show the jet later had decelerated to an apparent speed of four times faster than the speed of light.
In reality, nothing can exceed the speed of light, so this "superluminal" motion is an illusion. Because the jet is approaching Earth at nearly the speed of light, the light it emits at a later time has a shorter distance to go. In essence the jet is chasing its own light. In actuality more time has passed between the jet's emission of the light than the observer thinks. This causes the object's velocity to be overestimated -- in this case seemingly exceeding the speed of light.
"Our result indicates that the jet was moving at least at 99.97% the speed of light when it was launched," said Wenbin Lu of the University of California, Berkeley.
The Hubble measurements, combined with the VLBI measurements, announced in 2018, greatly strengthen the long-presumed connection between neutron star mergers and short-duration gamma-ray bursts. That connection requires a fast-moving jet to emerge, which has now been measured in GW170817.
This work paves the way for more precision studies of neutron star mergers, detected by the LIGO, Virgo, and KAGRA gravitational wave observatories. With a large enough sample over the coming years, relativistic jet observations might provide another line of inquiry into measuring the universe's expansion rate, associated with a number known as the Hubble constant.
At present there is a discrepancy between Hubble constant values as estimated for the early universe and nearby universe -- one of the biggest mysteries in astrophysics today. The differing values are based on extremely precise measurements of Type Ia supernovae by Hubble and other observatories, and Cosmic Microwave Background

measurements by ESA's Planck satellite.
More views of relativistic jets could add information for astronomers trying to solve the puzzle.
The Hubble Space Telescope is a project of international cooperation between NASA and ESA. NASA's Goddard Space Flight Centre in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore, Maryland, conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy, in Washington, D.C.

- 'Wobbling black hole' most extreme example ever detected

Gravitational waves identify what could be a rare one-in-1000 event
Date: October 12, 2022
Source: Cardiff University



Researchers at Cardiff University have identified a peculiar twisting motion in the orbits of two colliding black holes, an exotic phenomenon predicted by Einstein's theory of gravity.
Their study, which is published in Nature and led by Professor Mark Hannam, Dr Charlie Hoy and Dr Jonathan Thompson, reports that this is the first time this effect, known as precession, has been seen in black holes, where the twisting is 10 billion times faster than in previous observations.
The binary black hole system was found through gravitational waves in early 2020 in the Advanced LIGO and Virgo detectors. One of the black holes, 40 times bigger than our Sun, is likely the fastest spinning black hole to be found through gravitational waves. And unlike all previous observations, the rapidly revolving black hole distorted space and time so much that the binary's entire orbit wobbled back and forth.
This form of precession is specific to Einstein's theory of general relativity. These results confirm its existence in the most extreme physical event we can observe, the collision of two black holes.
"We've always thought that binary black holes can do this," said Professor Mark Hannam of Cardiff University's Gravity Exploration Institute. "We have been hoping to spot an example ever since the first gravitational wave detections. We had to wait for five years and over 80 separate detections, but finally we have one!"
A more down-to-earth example of precession is the wobbling of a spinning top, which may wobble -- or precess -- once every few seconds. By contrast, precession in general relativity is usually such a weak effect that it is imperceptible. In the fastest example previously measured from orbiting neutron stars called binary pulsars, it took over 75 years for the orbit to precess. The black-hole binary in this study, colloquially known as GW200129 (named after the date it was observed, January 29, 2020), precesses several times every second -- an effect 10 billion times stronger than measured previously.
Dr Jonathan Thompson, also of Cardiff University, explained: "It's a very tricky effect to identify. Gravitational waves are extremely weak and to detect them requires the most sensitive measurement apparatus in history. The precession is an even weaker effect buried inside the already weak signal, so we had to do a careful analysis to uncover it."
Gravitational waves were predicted by Einstein in 1916. They were first directly detected from the merger of two black holes by the Advanced LIGO instruments in 2015, a breakthrough discovery that led to the 2017 Nobel Prize. Gravitational wave astronomy is now one of the most vibrant fields of science, with a network of the Advanced LIGO, Virgo and KAGRA detectors operating in the US, Europe and Japan. To date there have been over 80 detections, all of merging black holes or neutron stars.
"So far most black holes we've found with gravitational waves have been spinning fairly slowly," said Dr Charlie Hoy, a researcher at Cardiff University during this study, and now at the University of Portsmouth. "The larger black hole in this binary, which was about 40 times more massive than the Sun, was spinning almost as fast as physically possible. Our current models of how binaries form suggest this one was extremely rare, maybe a one in a thousand event. Or it could be a sign that our models need to change."

The international network of gravitational-wave detectors is currently being upgraded and will start its next search of the universe in 2023. They are likely to find hundreds more black holes colliding, and will tell scientists whether GW200129 was a rare exception, or a sign that our universe is even stranger than they thought.
The authors were supported in part by funding from the Science and Technology Facilities Council (STFC) and European Research Council (ERC).

- Black hole spews out material years after shredding star

Date: October 12, 2022
Source: Harvard-Smithsonian Centre for Astrophysics

Credit: DESY, Science Communication Lab

In October 2018, a small star was ripped to shreds when it wandered too close to a black hole in a galaxy located 665 million light years away from Earth. Though it may sound thrilling, the event did not come as a surprise to astronomers who occasionally witness these violent incidents while scanning the night sky.
But nearly three years after the massacre, the same black hole is lighting up the skies again -- and it hasn't swallowed anything new, scientists say.
"This caught us completely by surprise -- no one has ever seen anything like this before," says Yvette Cendes, a research associate at the Centre for Astrophysics | Harvard & Smithsonian (CfA) and lead author of a new study analysing the phenomenon.
The team concludes that the black hole is now ejecting material traveling at half of the speed of light, but are unsure why the outflow was delayed by several years. The results, described this week in the *Astrophysical Journal*, may help scientists better understand black holes' feeding behaviour, which Cendes likens to "burping" after a meal.
The team spotted the unusual outburst while revisiting tidal disruption events (TDEs) -- when encroaching stars are spaghettified by black holes -- that occurred over the last several years.
Radio data from the Very Large Array (VLA) in New Mexico showed that the black hole had mysteriously reanimated in June 2021. Cendes and the team rushed to examine the event more closely.
"We applied for Director's Discretionary Time on multiple telescopes, which is when you find something so unexpected, you can't wait for the normal cycle of telescope proposals to observe it," Cendes explains. "All the applications were immediately accepted."
The team collected observations of the TDE, dubbed AT2018hyz, in multiple wavelengths of light using the VLA, the ALMA Observatory in Chile, MeerKAT in South Africa, the Australian Telescope Compact Array in Australia, and the Chandra X-Ray Observatory and the Neil Gehrels Swift Observatory in space.
Radio observations of the TDE proved the most striking.
"We have been studying TDEs with radio telescopes for more than a decade, and we sometimes find they shine in radio waves as they spew out material while the star is first being consumed by the black hole," says Edo Berger, professor of astronomy at Harvard University and the CfA, and co-author on the new study. "But in AT2018hyz there was radio silence for the first three years, and now it's dramatically lit up to become one of the most radio luminous TDEs ever observed."
Sebastian Gomez, a postdoctoral fellow at the Space Telescope Science Institute and co-author on the new paper, says that AT2018hyz was "unremarkable" in 2018 when he first studied it using visible light telescopes, including the 1.2-m telescope at the Fred Lawrence Whipple Observatory in Arizona.
Gomez, who was working on his doctoral dissertation with Berger at the time, used theoretical models to calculate that the star torn apart by the black hole was only one tenth the mass of our Sun.
"We monitored AT2018hyz in visible light for several months until it faded away, and then set it out of our minds," Gomez says.
TDEs are well-known for emitting light when they occur. As a star nears a black hole, gravitational forces begin to stretch, or spaghettify, the star. Eventually, the elongated material spirals around the black hole and

heats up, creating a flash that astronomers can spot from millions of light years away.
Some spaghettified material occasionally gets flung out back into space. Astronomers liken it to black holes being messy eaters -- not everything they try to consume makes it into their mouths.
But the emission, known as an outflow, normally develops quickly after a TDE occurs -- not years later. "It's as if this black hole has started abruptly burping out a bunch of material from the star it ate years ago," Cendes explains.
In this case, the burps are resounding.
The outflow of material is traveling as fast as 50 percent the speed of light. For comparison, most TDEs have an outflow that travels at 10 percent the speed of light, Cendes says.
"This is the first time that we have witnessed such a long delay between the feeding and the outflow," Berger says. "The next step is to explore whether this actually happens more regularly and we have simply not been looking at TDEs late enough in their evolution."
Additional co-authors on the study include Kate Alexander and Aprajita Hajela of Northwestern University; Ryan Chornock, Raffaella Margutti and Daniel Brethauer of the University of California, Berkley; Tanmoy Laskar of Radboud University; Brian Metzger of Columbia University; Michael Bietenholz of York University and Mark Wieringa of the Australia Telescope National Facility.

- ❖ Black hole discovered firing jets at neighbouring galaxy

Date: October 12, 2022
Source: Royal Astronomical Society

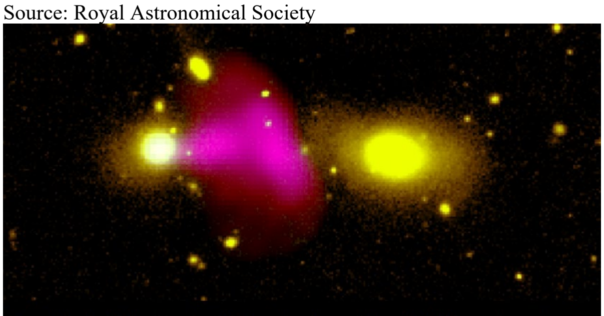


Image of the black hole within galaxy RAD12 spewing a large unipolar radio bubble on to its merging companion galaxy.
Credit: *Dr Ananda Hota, GMRT, CFHT, MeerKAT*
Licence type: *Attribution (CC BY 4.0)*

With the help of citizen scientists, a team of astronomers has discovered a unique black hole spewing a fiery jet at another galaxy. The black hole is hosted by a galaxy around one billion light years away from Earth named RAD12. The work was published today in *Monthly Notices of the Royal Astronomical Society (Letters)*.
Galaxies are typically divided into two major classes based on their morphology: spirals and ellipticals. Spirals have optically-blue looking spiral arms with an abundance of cold gas and dust. In spiral galaxies, new stars form at an average rate of one Sun-like star per year. In contrast elliptical galaxies appear yellowish and lack distinct features such as spiral arms. Star formation in elliptical galaxies is very scarce; it is still a mystery to astronomers as to why the elliptical galaxies we see today have not been forming new stars for billions of years. Evidence suggests that supermassive or 'monster' black holes are responsible. These 'monster' black holes spew gigantic jets made of electrons moving at very high speeds at other galaxies, depleting the fuel required for future star formation: cold gas and dust.
The unique nature of RAD12 had been observed in 2013 using optical data from the Sloan Digitised Sky Survey (SDSS) and radio data from the Very Large Array (FIRST survey). However, follow-up observation with the Giant Meterwave Radio Telescope (GMRT) in India was required to confirm its truly exotic nature: The black hole in RAD12 appears to be ejecting the jet only towards a neighbouring galaxy, named RAD12-B. In all cases, jets are ejected in pairs, moving in opposite directions at relativistic speeds. Why only one jet is seen coming from RAD12 remains a puzzle to astronomers.
A conical stem of young plasma is seen being ejected from the centre and reaches far beyond the visible stars of RAD12. The GMRT observations revealed that the fainter and older plasma extends far beyond the central conical stem and flares out like the cap of a mushroom (seen in red in the tricolour image). The whole structure is 440 thousand light years long, which is much larger than the host galaxy itself.
RAD12 is unlike anything known so far; this is the first time a jet has been observed to collide with a large galaxy like RAD12-B. Astronomers are now one step closer to understanding the impact of such interactions on elliptical galaxies, which may leave them with little cold gas for future star formation.
Research lead Dr Ananda Hota says, "We are excited to have spotted a rare system that helps us understand radio jet feedback of supermassive black holes on star formation of galaxies during mergers. Observations with the GMRT and data from various other telescopes such as the MeerKAT radio

telescope strongly suggest that the radio jet in RAD12 is colliding with the companion galaxy. An equally important aspect of this research is the demonstration of public participation in making discoveries through the RAD@home Citizen Science research collaboratory."

- NASA confirms DART mission impact changed asteroid's motion in space

Date: October 11, 2022
Source: NASA

Image of asteroid Didymos (L) and its moonlet, Dimorphos, before the impact of NASA's Double Asteroid Redirection Test (DART) spacecraft on Sept. 26, 2022. (Credit: NASA/Johns Hopkins APL)

Analysis of data obtained over the past two weeks by NASA's Double Asteroid Redirection Test (DART) investigation team shows the spacecraft's kinetic impact with its target asteroid, Dimorphos, successfully altered the asteroid's orbit. This marks humanity's first time purposely changing the motion of a celestial object and the first full-scale demonstration of asteroid deflection technology.

"All of us have a responsibility to protect our home planet. After all, it's the only one we have," said NASA Administrator Bill Nelson. "This mission shows that NASA is trying to be ready for whatever the universe throws at us. NASA has proven we are serious as a defender of the planet. This is a watershed moment for planetary defence and all of humanity, demonstrating commitment from NASA's exceptional team and partners from around the world."

Prior to DART's impact, it took Dimorphos 11 hours and 55 minutes to orbit its larger parent asteroid, Didymos. Since DART's intentional collision with Dimorphos on Sept. 26, astronomers have been using telescopes on Earth to measure how much that time has changed. Now, the investigation team has confirmed the spacecraft's impact altered Dimorphos' orbit around Didymos by 32 minutes, shortening the 11 hour and 55-minute orbit to 11 hours and 23 minutes. This measurement has a margin of uncertainty of approximately plus or minus 2 minutes.

Before its encounter, NASA had defined a minimum successful orbit period change of Dimorphos as change of 73 seconds or more. This early data show DART surpassed this minimum benchmark by more than 25 times.

"This result is one important step toward understanding the full effect of DART's impact with its target asteroid" said Lori Glaze, director of NASA's Planetary Science Division at NASA Headquarters in Washington. "As new data come in each day, astronomers will be able to better assess whether, and how, a mission like DART could be used in the future to help protect Earth from a collision with an asteroid if we ever discover one headed our way."

The investigation team is still acquiring data with ground-based observatories around the world -- as well as with radar facilities at NASA Jet Propulsion Laboratory's Goldstone planetary radar in California and the National Science Foundation's Green Bank Observatory in West Virginia. They are updating the period measurement with frequent observations to improve its precision.

Focus now is shifting toward measuring the efficiency of momentum transfer from DART's roughly 14,000-mile (22,530-kilometer) per hour collision with its target. This includes further analysis of the "ejecta" -- the many tons of asteroidal rock displaced and launched into space by the impact. The recoil from this blast of debris substantially enhanced DART's push against Dimorphos -- a little like a jet of air streaming out of a balloon sends the balloon in the opposite direction.

To successfully understand the effect of the recoil from the ejecta, more information on of the asteroid's physical properties, such as the characteristics of its surface, and how strong or weak it is, is needed. These issues are still being investigated.

"DART has given us some fascinating data about both asteroid properties and the effectiveness of a kinetic impactor as a planetary defence technology," said Nancy Chabot, the DART coordination lead from the Johns Hopkins Applied Physics Laboratory (APL) in Laurel, Maryland. "The DART team is continuing to work on this rich dataset to fully understand this first planetary defence test of asteroid deflection."

For this analysis, astronomers will continue to study imagery of Dimorphos from DART's terminal approach and from the Light Italian CubeSat for Imaging of Asteroids (LICIACube), provided by the Italian Space Agency, to approximate the asteroid's mass and shape. Roughly four years from now, the European Space Agency's Hera project is also planned to conduct detailed surveys of both Dimorphos and Didymos, with a particular focus on the crater left by DART's collision and a precise measurement of Dimorphos' mass.

Johns Hopkins APL built and operated the DART spacecraft and manages the DART mission for NASA's Planetary Defense Coordination Office as a project of the agency's Planetary Missions Program Office.

Telescopic facilities contributing to the observations used by the DART team to determine this result include: Goldstone, Green Bank Observatory, Swope Telescope at the Las Campanas Observatory in Chile, the Danish Telescope at the La Silla Observatory in Chile, and the Las Cumbres Observatory global telescope network facilities in Chile and in South Africa.

Neither Dimorphos nor Didymos poses any hazard to Earth before or after DART's controlled collision with Dimorphos.

For more information about the DART mission, visit: https://www.nasa.gov/dart