South Downs Mercury

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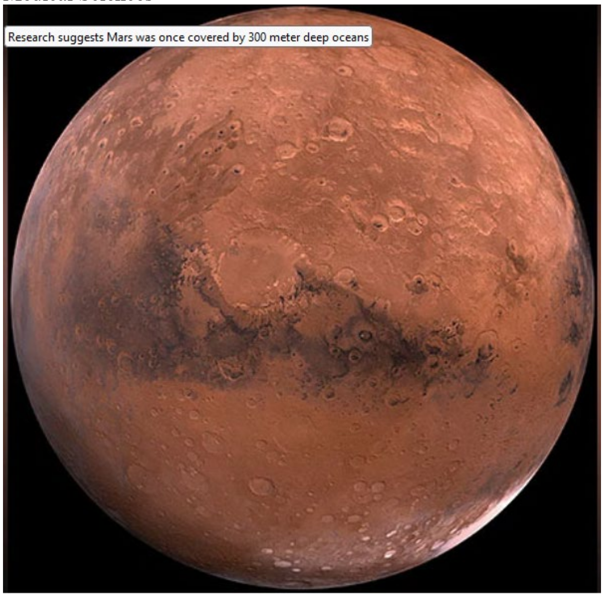
Main Speaker Peter Grimley Multi Messenger Astronomy
Lisa Lacey is standing down as Secretary by the end of August, we need a replacement to take over from her before she stands down

- Mars was once covered by 300-meter-deep oceans, study shows

Date: November 17, 2022
Source: University of Copenhagen - The Faculty of Health and Medical Sciences



Mars is called the red planet. But once, it was actually blue and covered in water, bringing us closer to finding out if Mars had ever harboured life.
Most researchers agree that there has been water on Mars, but just how much water is still debated.
Now a study from the University of Copenhagen shows that some 4.5 billion years ago, there was enough water for the entire planet to be covered in a 300-metre-deep ocean.
"At this time, Mars was bombarded with asteroids filled with ice. It happened in the first 100 million years of the planet's evolution. Another interesting angle is that the asteroids also carried organic molecules that are biologically important for life," says Professor Martin Bizzarro from the Centre for Star and Planet Formation.
In addition to water, the icy asteroids also brought biologically relevant molecules such as amino acids to the Red Planet. Amino acids are used when DNA and RNA form bases that contain everything a cell needs.
The study was published in the journal *Science Advances*.

Mars may have had the conditions for life before Earth

The new study indicates that the oceans that covered the entire planet in water were at least 300 metres deep. They may have been up to one kilometre deep. In comparison, there is actually very little water on Earth, explains Martin Bizzarro.
"This happened within Mars's first 100 million years. After this period, something catastrophic happened for potential life on Earth. It is believed that there was a gigantic collision between the Earth and another Mars-sized planet. It was an energetic collision that formed the Earth-Moon system and, as the same time, wiped out all potential life on Earth," says Martin Bizzarro.
Therefore, the researchers have really strong evidence that conditions allowing the emergence of life were present on Mars long before Earth.

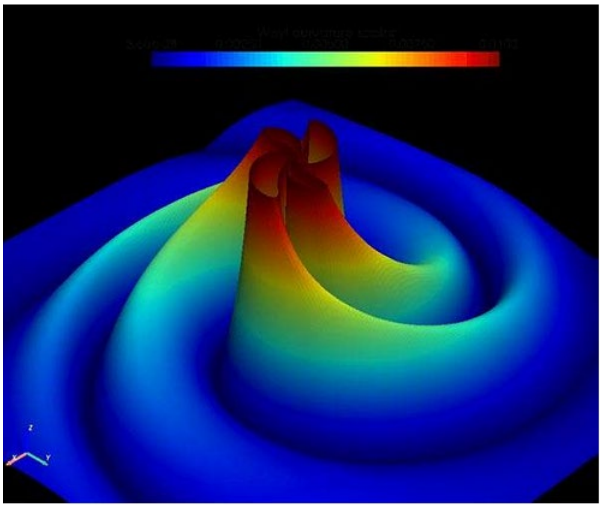
Billion-year-old meteorite

It was by means of a meteorite that is billions of years old that the researchers have been able to look into Mars's past history. The meteorite was once part of Mars's original crust and offers a unique insight into what happened at the time when the solar system was formed.
The whole secret is hiding in the way Mars's surface has been created -- and of which the meteorite was once a part -- because it is a surface that does not move. On Earth it is opposite. The tectonic plates are in perpetual motion and recycled in the planet's interior.
"Plate tectonics on Earth erased all evidence of what happened in the first 500 million years of our planet's history. The plates constantly move and are recycled back and destroyed into the interior of our planet. In contrast, Mars does not have plate tectonics

such that planet's surface preserves a record of the earliest history of the planet," explains Martin Bizzarro.

- ❖ Black holes in eccentric orbit

Date: November 18, 2022
Source: Friedrich-Schiller-Universitaet Jena



Numerical simulation representing the curvature of spacetime during the merger of the two black holes.

When black holes collide in the universe, the clash shakes up space and time: the amount of energy released during the merger is so great that it causes space-time to oscillate, similar to waves on the surface of water. These gravitational waves spread out through the entire universe and can still be measured thousands of light years away, as was the case on 21 May 2019, when the two gravitational wave observatories LIGO (USA) and Virgo (Italy) captured such a signal. Named GW190521 after the date of its discovery, the gravitational wave event has since provoked discussion among experts because it differs markedly from previously measured signals. The signal had initially been interpreted to mean that the collision involved two black holes moving in near-circular orbits around each other. "Such binary systems can be created by a number of astrophysical processes," explains Prof. Sebastiano Bernuzzi, a theoretical physicist from the University of Jena, Germany. Most of the black holes discovered by LIGO and Virgo, for example, are of stellar origin. "That means they are the remnants of massive stars in binary star systems," adds Bernuzzi, who led the current study. Such black holes orbit each other in quasi-circular orbits, just as the original stars did previously.

One black hole captures a second

"GW190521 behaves significantly differently, however," explains Rossella Gamba. The lead author of the publication is doing her doctorate in Jena Research Training Group 2522 and is part of Bernuzzi's team. "It's morphology and explosion-like structure are very different from previous observations." So, Rossella Gamba and her colleagues set out to find an alternative explanation for the unusual gravitational wave signal. Using a combination of state-of-the-art analytical methods and numerical simulations on supercomputers, they calculated different models for the cosmic collision. They came to the conclusion that it must have occurred on a strongly eccentric path instead of a quasi-circular one. A black hole initially moves freely in an environment that is relatively densely filled with matter and, as soon as it gets close to another black hole, it can be "captured" by the other's gravitational field. This also leads to the formation of a binary system, but here the two black holes do not orbit in a circle, but move eccentrically, in tumbling motions around each other.
"Such a scenario explains the observations much better than any other hypothesis presented so far. The probability is 1:4300," says Matteo Breschi, doctoral student and co-author of the study, who developed the infrastructure for the analysis. And postdoctoral researcher Dr Gregorio Carullo adds: "Even though we don't currently know exactly how common such dynamic movements by black holes are, we don't expect them to be a frequent occurrence." This makes the current results all the more exciting, he adds. Nevertheless, more research is needed to clarify beyond doubt the processes that created GW190521.

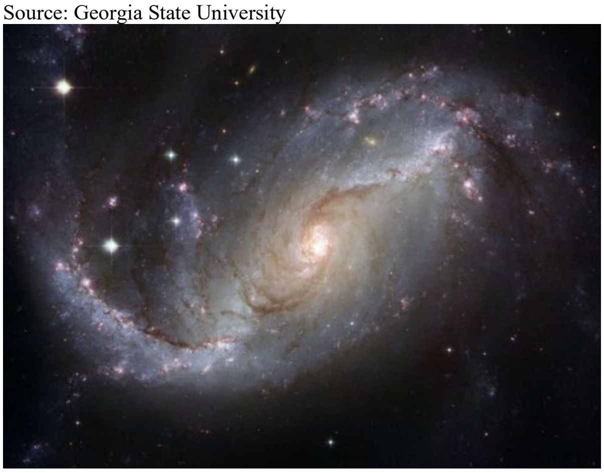
Teamwork in the Research Training Group

For the current project, the teams in Turin and Jena (as part of the German Research Foundation-funded Jena Research Training Group 2522 "Dynamics and Criticality in Quantum and Gravitational Systems") developed a general relativistic framework for the eccentric merger of black holes and verified the analytical predictions using simulations of Einstein's equations. For the first time, models of dynamic encounters were used in the analysis of gravitational wave observation data.

- ❖ Elusive, dusty inner region of distant galaxy

The long-sought after innermost dusty ring was detected with the highest spatial resolution in the infrared wavelengths ever used

Date: November 17, 2022
Source: Georgia State University



An international team of scientists has achieved the milestone of directly observing the long-sought, innermost dusty ring around a supermassive black hole, at a right angle to its emerging jet. Such a structure was thought to exist in the nucleus of galaxies but had been difficult to observe directly because intervening material obscured our line of sight.

Now the inner disk is detected using the highest spatial resolution in the infrared wavelengths ever done for an extragalactic object. The new discovery was just published in *The Astrophysical Journal*.

"This is a very exciting step forward to view the inner region of a distant galaxy with such fine detail," said Gail Schaefer, Associate Director of the Centre for High Angular Resolution Astronomy (CHARA) Array.

A supermassive black hole is thought to exist at the centre of every large galaxy. As material in the surrounding region gets pulled toward the centre, the gas forms a hot and bright disk-like structure. In some cases, a jet emerges from the vicinity of the black hole in a direction at a right angle to the disk.

However, this flat structure, which is essentially the 'engine' of this active supermassive black hole system, has never been directly seen because it's too small to be captured by conventional telescopes.

One way to approach this key structure is to directly see an outer 'dusty ring' -- interstellar gas contains dust grains, tiny solid particles made of heavy elements, which can only survive in the outer region where temperature is low enough (< ~1500K -- otherwise metals evaporate). The heated dust emits thermal infrared radiation, and thus would look like an outer ring around the black hole, if the central system indeed has a flat structure. The detection of its structure would be a key step to delineate how the central engine works.

Attempts to see this structure from edge-on directions are difficult, because the system is obscured by the same dust acting as an absorber of light. Instead, in the new investigation the team focused on a system with a face-on view, the brightest such object in the nearby universe. However, the detection needed very high spatial resolution in the infrared wavelengths, and at the same time, a large array of telescopes that is laid out suitably to observe objects at different orientations.

The Georgia State University CHARA Array interferometer at the Mount Wilson Observatory in California is the only facility which meets both of these requirements. The Array consists of 6 telescopes, each of which has a 1-meter diameter mirror, that are combined to achieve the spatial resolution of a much larger telescope. While each individual telescope is relatively small, the array layout is optimized to observe objects in a variety of angles and with large distances between telescopes. This achieves a very high spatial resolution capability. The CHARA Array actually has the sharpest eyes in the world in infrared wavelengths.

With the CHARA Array, the team finally detected the dusty ring, at a right angle to the emerging jet in the centre of the galaxy called NGC 4151.

"We've been hoping to see this structure in a bare nucleus object for a long, long time," says Makoto Kishimoto, principal investigator of the project at Kyoto Sangyo University.

A big boost was that each telescope has recently added a new system called "adaptive optics."

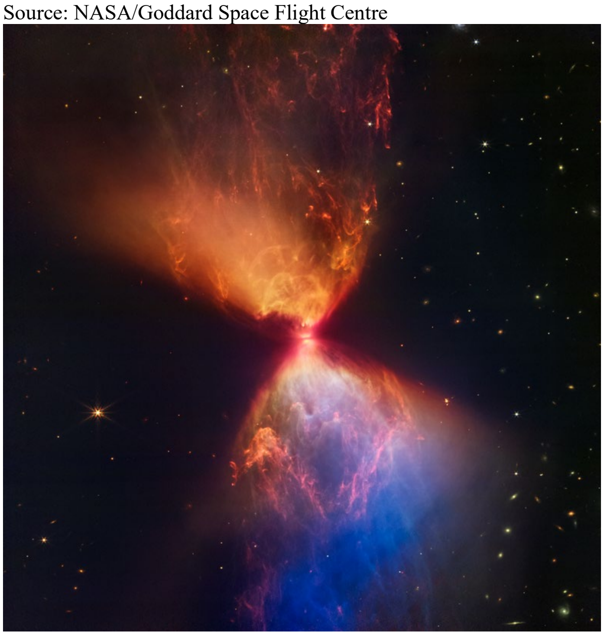
Matt Anderson, a postdoctoral researcher at the CHARA Array who played a critical role in conducting the observations, says "This greatly increased the injection rate of the light, compensating for the relatively small collecting mirror to observe the extragalactic target, which is much fainter than the stellar targets typically observed in our Galaxy."

Over the last nearly 40 years, researchers in the field believed that this dusty ring is a key to understanding different characteristics of

accreting supermassive blackhole systems. The properties we observe depend on whether we have an obscured, edge-on view or clear, face-on view of the nucleus of the active galaxy. The detection of this ring-like structure validates this model.
Furthermore, the detection probably is not just an indication of a flat structure. Additional studies have been showing that the structure seen at slightly longer infrared wavelengths, corresponding to an even larger outer region, seems elongated along the jet, and not at a right angle to it. This has been interpreted as an indication for a dusty wind being blown out toward the jet direction. The present finding that the inner structure looks flat and perpendicular to the jet, is an important link to the windy structure and its interaction with the rest of the galaxy surrounding the active black hole system.
These ground-breaking observations measured the size and orientation of the dusty disk. The team is working to get an even more detailed image of the central region by building a new instrument at the CHARA Array that can see deeper into space and resolve finer scale structure of the source.

- NASA's Webb catches fiery hourglass as new star forms

Date: November 17, 2022
Source: NASA/Goddard Space Flight Centre



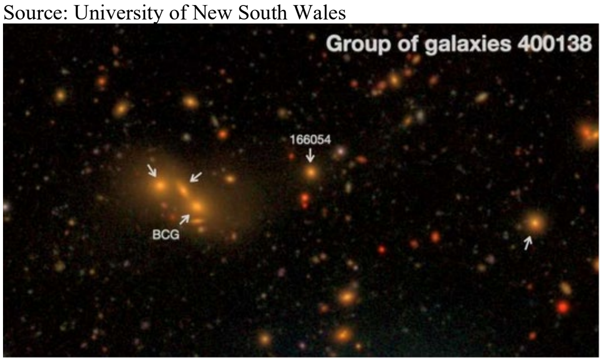
The protostar within the dark cloud L1527, shown in this image from NASA's James Webb Space Telescope Near-Infrared Camera (NIRCam), is embedded within a cloud of material feeding its growth. Ejections from the star have cleared out cavities above and below it, whose boundaries glow orange and blue in this infrared view. The upper central region displays bubble-like shapes due to stellar "burps," or sporadic ejections.
Credits: NASA, ESA, CSA, and STScI. Image processing: J. DePasquale, A. Pagan, and A. Koekemoer (STScI)

NASA's James Webb Space Telescope has revealed the once-hidden features of the protostar within the dark cloud L1527, providing insight into the beginnings of a new star. These blazing clouds within the Taurus star-forming region are only visible in infrared light, making it an ideal target for Webb's Near-Infrared Camera (NIRCam).
The protostar itself is hidden from view within the "neck" of this hourglass shape. An edge-on protoplanetary disk is seen as a dark line across the middle of the neck. Light from the protostar leaks above and below this disk, illuminating cavities within the surrounding gas and dust.
The region's most prevalent features, the clouds coloured blue and orange in this representative-colour infrared image, outline cavities created as material shoots away from the protostar and collides with surrounding matter. The colours themselves are due to layers of dust between Webb and the clouds. The blue areas are where the dust is thinnest. The thicker the layer of dust, the less blue light is able to escape, creating pockets of orange.
Webb also reveals filaments of molecular hydrogen that have been shocked as the protostar ejects material away from it. Shocks and turbulence inhibit the formation of new stars, which would otherwise form all throughout the cloud. As a result, the protostar dominates the space, taking much of the material for itself.
Despite the chaos that L1527 causes, it's only about 100,000 years old -- a relatively young body. Given its age and its brightness in far-infrared light as observed by missions like the Infrared Astronomical Satellite, L1527 is considered a class 0 protostar, the earliest stage of star formation. Protostars like these, which are still cocooned in a dark cloud of dust and gas, have a long way to go before they become full-fledged stars. L1527 doesn't generate its own energy through nuclear fusion of hydrogen yet, an essential characteristic of stars. Its shape, while mostly spherical, is also unstable, taking the form of a small, hot, and puffy clump of gas somewhere between 20 and 40% the mass of our Sun.
As the protostar continues to gather mass, its core gradually compresses and gets closer to stable nuclear fusion. The scene shown in this image reveals L1527 doing just that. The surrounding molecular cloud is made up of dense dust and gas being drawn to the centre, where the protostar resides. As the material

falls in, it spirals around the centre. This creates a dense disk of material, known as an accretion disk, which feeds material to the protostar. As it gains more mass and compresses further, the temperature of its core will rise, eventually reaching the threshold for nuclear fusion to begin.
The disk, seen in the image as a dark band in front of the bright centre, is about the size of our solar system. Given the density, it's not unusual for much of this material to clump together -- the beginnings of planets.
Ultimately, this view of L1527 provides a window into what our Sun and solar system looked like in their infancy.

- Astronomers observe intra-group light -- the elusive glow between distant galaxies

Date: November 23, 2022
Source: University of New South Wales



Light 'between' the groups of galaxies – the 'intra-group light' – however dim, is radiated from stars stripped from their home galaxy. Image: Supplied. Credit: Martínez-Lombilla et al./UNSW Sydney

An international team of astronomers have turned a new technique onto a group of galaxies and the faint light between them -- known as 'intra-group light' -- to characterise the stars that dwell there.
Lead author of the study published in *MNRAS*, Dr Cristina Martínez-Lombilla from the School of Physics at UNSW Science, said "We know almost nothing about intra-group light.
"The brightest parts of the intra-group light are ~50 times fainter than the darkest night sky on Earth. It is extremely hard to detect, even with the largest telescopes on Earth -- or in space."
Using their sensitive technique, which eliminates light from all objects except that from the intra-group light, the researchers not only detected the intra-group light but were able to study and tell the story of the stars that populate it.
"We analysed the properties of the intra-group stars -- those stray stars *between* the galaxy groups. We looked at the age and abundance of the elements that composed them and then we compared those features with the stars still belonging to galaxy groups," Dr Martínez-Lombilla said.
"We found that the intra-group light is younger and less metal-rich than the surrounding galaxies."

Rebuilding the story of intra-group light

Not only were the orphan stars in the intra-group light 'anachronistic' but they appeared to be of a different origin to their closest neighbours. The researchers found the character of the intra-group stars appeared similar to the nebulous 'tail' of a further away galaxy.
The combination of these clues allowed the researchers to rebuild the history -- the story -- of the intra-group light and how its stars came to be gathered in their own stellar orphanage.
"We think these individual stars were at some points stripped from their home galaxies and now they float freely, following the gravity of the group," said Dr Martínez-Lombilla. "The stripping, called tidal stripping, is caused by the passage of massive satellite galaxies -- similar to the Milky Way -- that pull stars in their wake."
This is the first time the intra-group light of these galaxies has been observed.
"Unveiling the quantity and origin of the intra-group light provides a fossil record of all the interactions a group of galaxies has undergone and provides a holistic view of the system's interaction history," Dr Martínez-Lombilla said.
"Also, these events occurred a long time ago. The galaxies [we're looking at] are so far away, that we're observing them as they were 2.5 billion years ago. That is how long it takes for their light to reach us."
By observing events from a long time ago, in galaxies so far away, the researchers are contributing vital datapoints to the slow-burning evolution of cosmic events.

Tailored image treatment procedure

The researchers pioneered a unique technique to achieve this penetrating view.
"We have developed a tailored image treatment procedure that allows us to analyse the faintest structures in the Universe," said Dr Martínez-Lombilla.
"It follows the standard steps for the study of faint structures in astronomical images -- which implies 2D modelling and the removal of all light except that coming from the intra-group light. This includes all the bright stars

in the images, the galaxies obscuring the intra-group light and a subtraction of the continuum emission from the sky.
"What makes our technique different is that it is fully Python-based so it is very modular and easily applicable to different sets of data from different telescopes rather than being just useful for these images.
"The most important outcome is that when studying very faint structures around galaxies, every step in the process counts and every undesirable light should be accounted for and removed. Otherwise, your measurements will be wrong.
The techniques presented in this study are a pilot, encouraging future analyses of intra-group light, Dr Martínez-Lombilla said.
"Our main long-term goal is to extend these results to a large sample of group of galaxies. Then we can look at statistics and find out the typical properties regarding the formation and evolution of the intra-group light and these extremely common systems of groups of galaxies.
"This is key work for preparing the next generation of deep all-sky surveys such as those to be performed with the Euclid space telescope and the LSST with the Vera C. Rubin Observatory."

- International team observes innermost structure of quasar jet

Date: November 22, 2022
Source: National Institutes of Natural Sciences

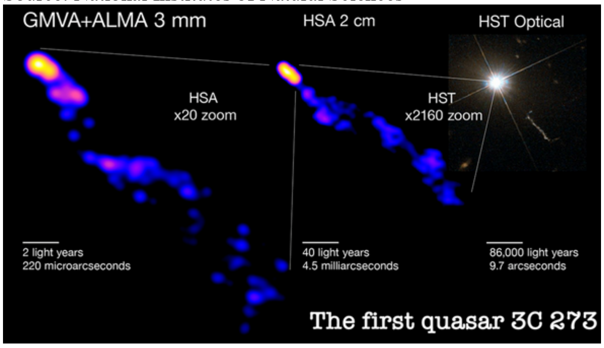


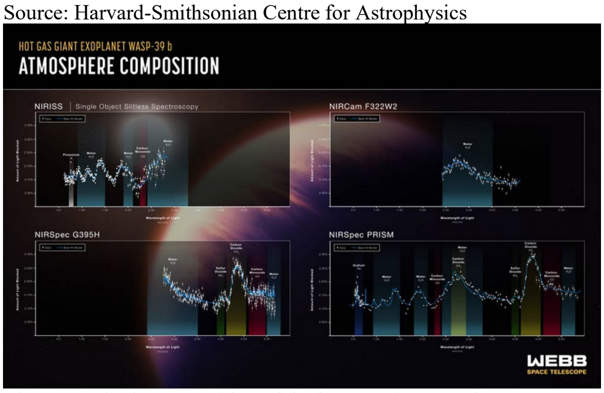
Fig: Radio astronomy images of the 3C 273 jet. The close-up view on the left is the deepest look yet into the plasma jet of the quasar 3C 273. The image in the centre shows the extended structure of the jet. The image on the right is a visible light image of the quasar taken by the Hubble Space Telescope. The radio observations were made by the Global Millimetre VLBI Array (GMVA) joined by the Atacama Large Millimetre/submillimetre Array (ALMA) and the High Sensitivity Array (HSA). (Credits: Hiroki Okino and Kazunori Akiyama; GMVA+ALMA and HSA images: Okino et al.; HST Image: ESA/Hubble & NASA

An international team of scientists has observed the narrowing of a quasar jet for the first time by using a network of radio telescopes across the world. The results suggest that the narrowing of the jet is independent of the activity level of the galaxy which launched it.

Nearly every galaxy hosts a supermassive black hole in its centre. In some cases, enormous amounts of energy are released by gas falling towards the black hole, creating a phenomenon known as a quasar. Quasars emit narrow, collimated jets of material at nearly the speed of light. But how and where quasar jets are collimated has been a long-standing mystery.
An international team led by Hiroki Okino, a graduate student at the University of Tokyo, and including members from the National Astronomical Observatory of Japan (NAOJ), the Massachusetts Institute of Technology, Kogakuin University, Hachinohe National College of Technology, and Niigata University, captured an image with the highest angular resolution to date that shows the deepest part of the jet in a bright quasar known as 3C 273. The team found that the jet flowing from the quasar narrows down over a very long distance. This narrowing part of the jet continues incredibly far, well beyond the area where the black hole's gravity dominates. The results show that the structure of the jet is similar to jets launched from nearby galaxies with a low luminosity active nucleus. This would indicate that the collimation of the jet is independent of the activity level in the host galaxy, providing an important clue to unravelling the inner workings of jets.

- An exoplanet atmosphere as never seen before

Date: November 22, 2022
Source: Harvard-Smithsonian Centre for Astrophysics



The atmospheric composition of the hot gas giant exoplanet WASP-39 b has been revealed by NASA's James Webb Space Telescope. This graphic shows four transmission spectra from three of Webb's instruments operated in four instrument modes. At upper left, data from NIRISS shows fingerprints of potassium (K), water (H2O), and carbon monoxide (CO). At upper right, data from NIRCam shows a prominent water signature. At lower left, data from NIRSpec indicates water, sulphur dioxide (SO2), carbon dioxide (CO2), and carbon monoxide (CO). At lower right, additional NIRSpec data reveals all of these molecules as well as sodium (Na).
Credits: NASA, ESA, CSA, J. Olmsted (STScI)
Download the full-resolution image from the Space Telescope Science Institute.

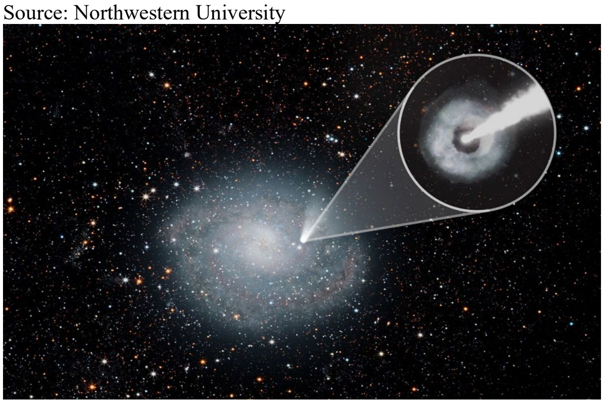
The James Webb Space Telescope (JWST) just scored another first: a detailed molecular

and chemical portrait of a distant world's skies.
The telescope's array of highly sensitive instruments was trained on the atmosphere of a "hot Saturn" -- a planet about as massive as Saturn orbiting a star some 700 light-years away -- known as WASP-39 b. While JWST and other space telescopes, including Hubble and Spitzer, previously have revealed isolated ingredients of this broiling planet's atmosphere, the new readings provide a full menu of atoms, molecules, and even signs of active chemistry and clouds.
"The clarity of the signals from a number of different molecules in the data is remarkable," says Mercedes López-Morales, an astronomer at the Centre for Astrophysics | Harvard & Smithsonian and one of the scientists who contributed to the new results.
"We had predicted that we were going to see many of those signals, but still, when I first saw the data, I was in awe," López-Morales adds.
The latest data also give a hint of how these clouds in exoplanets might look up close: broken up rather than a single, uniform blanket over the planet.
The findings bode well for the capability of JWST to conduct the broad range of investigations on exoplanets -- planets around other stars -- scientists hoped for. That includes probing the atmospheres of smaller, rocky planets like those in the TRAPPIST-1 system.
"We observed the exoplanet with multiple instruments that, together, provide a broad swath of the infrared spectrum and a panoply of chemical fingerprints inaccessible until JWST," said Natalie Batalha, an astronomer at the University of California, Santa Cruz, who contributed to and helped coordinate the new research. "Data like these are a game changer."
The suite of discoveries is detailed in a set of five newly submitted scientific papers, available on the preprint website arXiv. Among the unprecedented revelations is the first detection in an exoplanet atmosphere of sulphur dioxide, a molecule produced from chemical reactions triggered by high-energy light from the planet's parent star. On Earth, the protective ozone layer in the upper atmosphere is created in a similar way.
"The surprising detection of sulphur dioxide finally confirms that photochemistry shapes the climate of 'hot Saturn's,'" says Diana Powell, a NASA Hubble fellow, astronomer at the Centre for Astrophysics and core member of the team that made the sulphur dioxide discovery. "Earth's climate is also shaped by photochemistry, so our planet has more in common with 'hot Saturn's' than we previously knew!"
Jea Adams a graduate student at Harvard and researcher at the Centre for Astrophysics analysed the data that confirmed the sulphur dioxide signal.
"As an early career researcher in the field of exoplanet atmospheres, it's so exciting to be a part of a detection like this," Adams says. "The process of analysing this data felt magical. We saw hints of this feature in early data, but this higher precision instrument revealed the signature of SO2 clearly and helped us solve the puzzle."
At an estimated temperature of 1,600 degrees Fahrenheit and an atmosphere made mostly of hydrogen, WASP-39 b is not believed to be habitable. The exoplanet has been compared to both Saturn and Jupiter, with a mass similar to Saturn, but an overall size as big as Jupiter. But the new work points the way to finding evidence of potential life on a habitable planet.
The planet's proximity to its host star -- eight times closer than Mercury is to our Sun -- also makes it a laboratory for studying the effects of radiation from host stars on exoplanets. Better knowledge of the star-planet connection should bring a deeper understanding of how these processes create the diversity of planets observed in the galaxy.
Other atmospheric constituents detected by JWST include sodium, potassium, and water vapor, confirming previous space and ground-based telescope observations as well as finding additional water features, at longer wavelengths, that haven't been seen before. JWST also saw carbon dioxide at higher resolution, providing twice as much data as reported from its previous observations. Meanwhile, carbon monoxide was detected, but obvious signatures of both methane and hydrogen sulphide were absent from the data. If present, these molecules occur at very low levels, a significant finding for scientists making inventories of exoplanet chemistry in order to better understand the formation and development of these distant worlds.
Capturing such a broad spectrum of WASP-39 b's atmosphere was a scientific tour de

force, as an international team numbering in the hundreds independently analysed data from four of JWST's finely calibrated instrument modes. They then made detailed inter-comparisons of their findings, yielding yet more scientifically nuanced results.
JWST views the universe in infrared light, on the red end of the light spectrum beyond what human eyes can see; that allows the telescope to pick up chemical fingerprints that can't be detected in visible light.
Each of the three instruments even has some version of the "IR" of infrared in its name: NIRSpec, NIRCam, and NIRISS.
To see light from WASP-39 b, JWST tracked the planet as it passed in front of its star, allowing some of the star's light to filter through the planet's atmosphere. Different types of chemicals in the atmosphere absorb different colours of the starlight spectrum, so the colours that are missing tell astronomers which molecules are present.
By so precisely parsing an exoplanet atmosphere, the JWST instruments performed well beyond scientists' expectations -- and promise a new phase of exploration among the broad variety of exoplanets in the galaxy.
López-Morales says, "I am looking forward to seeing what we find in the atmospheres of small, terrestrial planets."

- Short gamma-ray bursts traced farther into distant universe

Most robust inventory to date catalogues SGRBs' host galaxies, characteristics
Date: November 21, 2022
Source: Northwestern University



Credit: W. M. Keck Observatory/Adam Makarenko
A Northwestern University-led team of astronomers has developed the most extensive inventory to date of the galaxies where short gamma-ray bursts (SGRBs) originate.
Using several highly sensitive instruments and sophisticated galaxy modelling, the researchers pinpointed the galactic homes of 84 SGRBs and probed the characteristics of 69 of the identified host galaxies. Among their findings, they discovered that about 85% of the studied SGRBs come from young, actively star-forming galaxies.
The astronomers also found that more SGRBs occurred at earlier times, when the universe was much younger -- and with greater distances from their host galaxies' centres -- than previously known. Surprisingly, several SGRBs were spotted far outside their host galaxies -- as if they were "kicked out," a finding that raises questions as to how they were able to travel so far away.
"This is the largest catalogue of SGRB host galaxies to ever exist, so we expect it to be the gold standard for many years to come," said Anya Nugent, a Northwestern graduate student who led the study focused on modelling host galaxies. "Building this catalogue and finally having enough host galaxies to see patterns and draw significant conclusions is exactly what the field needed to push our understanding of these fantastic events and what happens to stars after they die."
The team will publish two papers, detailing the new catalogue. Both papers will publish on Monday, Nov. 21 in *The Astrophysical Journal.* Because SGRBs are among the brightest explosions in the universe, the team calls its catalogue BRIGHT (Broadband Repository for Investigating Gamma-ray burst Host Traits). All of BRIGHT's data and modelling products are publicly available online for community use.
Nugent is a graduate student in physics and astronomy at Northwestern's Weinberg College of Arts and Sciences and a member of the Centre for Interdisciplinary Exploration and Research in Astrophysics (CIERA). She is advised by Wen-fai Fong, an assistant professor of physics and astronomy at Weinberg and a key member of CIERA, who led a second study focused on SGRB host observations.
Benchmark for future comparisons
When two neutron stars collide, they generate momentary flashes of intense gamma-ray light, known as SGRBs. While the gamma rays last mere seconds, the optical light can continue for hours before fading below detection levels (an event called an afterglow). SGRBs are some of the most luminous explosions in the universe with, at most, a dozen detected and pinpointed each year. They currently represent the only way to

study and understand a large population of merging neutron star systems.
Since NASA's Neil Gehrels Swift Observatory first discovered an SGRB afterglow in 2005, astronomers have spent the last 17 years trying to understand which galaxies produce these powerful bursts. Stars within a galaxy can give insight into the environmental conditions needed to produce SGRBs and can connect the mysterious bursts to their neutron-star merger origins. So far, only one SGRB (GRB 170817A) has a confirmed neutron-star merger origin -- as it was detected just seconds after gravitational wave detectors observed the binary neutron-star merger (GW170817).
"In a decade, the next generation of gravitational wave observatories will be able to detect neutron star mergers out to the same distances as we do SGRBs today," Fong said. "Thus, our catalogue will serve as a benchmark for comparison to future detections of neutron star mergers."
"The catalogue can really make impacts beyond just a single class of transients like SGRBs," said Yuxin "Vic" Dong, study co-author and astrophysics Ph.D. student at Northwestern. "With the wealth of data and results presented in the catalogue, I believe a variety of research projects will make use of it, maybe even in ways we have yet not thought of."

Insight into neutron-star systems

To create the catalogue, the researchers used several highly sensitive instruments at W.M. Keck Observatory, the Gemini Observatories, the MMT Observatory, the Large Binocular Telescope Observatory and the Magellan Telescopes at Las Campanas Observatory to capture deep imaging and spectroscopy of some of the faintest galaxies identified in the survey of SGRB hosts. The team also used data from two of NASA's Great Observatories, the Hubble Space Telescope and Spitzer Space Telescope.
Prior to these new studies, astronomers characterized host galaxies from only a couple dozen SGRBs. The new catalogue is quadruple the number of existing samples.
With the advantage of a much larger dataset, the catalogue shows that SGRB host galaxies can be either young and star-forming *or* old and approaching death. This means neutron-star systems form in a broad range of environments and many of them have quick formation-to-merger timescales. Because neutron-star mergers create heavy elements like gold and platinum, the catalogue's data also will deepen scientists' understanding of when precious metals were first created in the universe.
"We suspect that the younger SGRBs we found in younger host galaxies come from binary stellar systems that formed in a star formation 'burst' and are so tightly bound that they can merge very fast," Nugent said. "Long-standing theories have suggested there must be ways to merge neutron stars quickly, but, until now, we have not been able to witness them. We find evidence for older SGRBs in the galaxies that are much older and believe the stars in those galaxies either took a longer time to form a binary or were a binary system that was further separated. Hence, those took longer to merge."

Potential of JWST

With the ability to detect the faintest host galaxies from very early times in the universe, NASA's new infrared flagship observatory, the James Webb Space Telescope (JWST), is poised to further advance the understanding of neutron star mergers and how far back in time they began.
"I'm most excited about the possibility of using JWST to probe deeper into the homes of these rare, explosive events," Nugent said. "JWST's ability to observe faint galaxies in the universe could uncover more SGRB host galaxies that are currently evading detection, perhaps even revealing a missing population and a link to the early universe."
"I started observations for this project 10 years ago, and it was so gratifying to be able to pass the torch onto the next generation of researchers," Fong said. "It is one of my career's greatest joys to see years of work come to life in this catalogue, thanks to the young researchers who really took this study to the next level."
The studies were supported by the National Science Foundation (award numbers AST-1814782 and AST-2047919), the David and Lucile Packard Foundation, the Alfred P. Sloan Foundation and the Research Corporation for Scientific Advancement.

- The tilt in our stars: The shape of the Milky Way's halo of stars is realized

Date: November 18, 2022
Source: Harvard-Smithsonian Centre for Astrophysics

A new study has revealed the true shape of the diffuse cloud of stars surrounding the disk of our galaxy. For decades, astronomers have thought that this cloud of stars -- called the stellar halo -- was largely spherical, like a beach ball. Now a new model based on modern observations shows the stellar halo is oblong and tilted, much like a football that has just been kicked.
The findings -- published this month *The Astronomical Journal* -- offer insights into a host of astrophysical subject areas. The results, for example, shed light on the history of our galaxy and galactic evolution, while also offering clues in the ongoing hunt for the mysterious substance known as dark matter.
"The shape of the stellar halo is a very fundamental parameter that we've just measured to greater accuracy than was possible before," says study lead author Jiwon "Jesse" Han, a PhD student at the Centre for Astrophysics | Harvard & Smithsonian.
"There are a lot of important implications of the stellar halo not being spherical but instead shaped like a football, rugby ball, or zeppelin -- take your pick!"
"For decades, the general assumption has been that the stellar halo is more or less spherical and isotropic, or the same in every direction," adds study co-author Charlie Conroy, Han's advisor, and a professor of astronomy at Harvard University and the Centre for Astrophysics. "We now know that the textbook picture of our galaxy embedded within a spherical volume of stars has to be thrown out."
The Milky Way's stellar halo is the visible portion of what is more broadly called the galactic halo. This galactic halo is dominated by invisible dark matter, whose presence is only measurable through the gravity that it exerts. Every galaxy has its own halo of dark matter. These halos serve as a sort of scaffold upon which ordinary, visible matter hangs. In turn, that visible matter forms stars and other observable galactic structure. To better understand how galaxies form and interact, as well as the underlying nature of dark matter, stellar haloes are accordingly valuable astrophysical targets.
"The stellar halo is a dynamic tracer of the galactic halo," says Han. "In order to learn more about galactic haloes in general, and especially our own galaxy's galactic halo and history, the stellar halo is a great place to start."
Fathoming the shape of the Milky Way's stellar halo, though, has long challenged astrophysicists for the simple reason that we are embedded within it. The stellar halo extends out several hundred thousand light years above and below the star-filled plane of our galaxy, where our Solar System resides.
"Unlike with external galaxies, where we just look at them and measure their halos," says Han, "we lack the same sort of aerial, outside perspective of our own galaxy's halo."
Complicating matters further, the stellar halo has proven to be quite diffuse, containing only about one percent of the mass of all the galaxy's stars. Yet over time, astronomers have succeeded in identifying many thousands of stars that populate this halo, which are distinguishable from other Milky Way stars due to their distinctive chemical makeup (gaugeable by studies of their starlight), as well as by their distances and motions across the sky. Through such studies, astronomers have realized that halo stars are not evenly distributed. The goal has since been to study the patterns of over-densities of stars -- spatially appearing as bunches and streams -- to sort out the ultimate origins of the stellar halo.
The new study by CfA researchers and colleagues leverages two major datasets gathered in recent years that have plumbed the stellar halo as never before.
The first set is from Gaia, a revolutionary spacecraft launched by the European Space Agency in 2013. Gaia has continued compiling the most precise measurements of the positions, motions, and distances of millions of stars in the Milky Way, including some nearby stellar halo stars.
The second dataset is from H3 (Hectochelle in the Halo at High Resolution), a ground-based survey conducted at the MMT, located at the Fred Lawrence Whipple Observatory in Arizona, and a collaboration between the CfA and the University of Arizona. H3 has

gathered detailed observations of tens of thousands of stellar halo stars too far away for Gaia to assess.

Combining these data in a flexible model that allowed for the stellar halo shape to emerge from all the observations yielded the decidedly non-spherical halo -- and the football shape nicely dovetails with other findings to date. The shape, for example, independently and strongly agrees with a leading theory regarding the formation of the Milky Way's stellar halo.

According to this framework, the stellar halo formed when a lone dwarf galaxy collided 7-10 billion years ago with our far-larger galaxy. The departed dwarf galaxy is amusingly known as Gaia-Sausage-Enceladus (GSE), where "Gaia" refers to the aforementioned spacecraft, "Sausage" for a pattern appearing when plotting the Gaia data and "Enceladus" for the Greek mythological giant who was buried under a mountain -- rather like how GSE was buried in the Milky Way. As a consequence of this galactic collisional event, the dwarf galaxy was ripped apart and its constituent stars strewn out into a dispersed halo. Such an origin story accounts for the stellar halo stars' inherent unlikeness to stars born and bred in the Milky Way.

The study's results further chronicle just how GSE and the Milky Way interacted all those eons ago. The football shape -- technically called a triaxial ellipsoid -- reflects the observations of two pileups of stars in the stellar halo. The pileups ostensibly formed when GSE went through two orbits of the Milky Way. During these orbits, GSE would have slowed down twice at so-called apocenters, or the furthest points in the dwarf galaxy's orbit of the greater gravitational attractor, the hefty Milky Way; these pauses led to the extra shedding of GSE stars.

Meanwhile, the tilt of the stellar halo indicates that GSE encountered the Milky Way at an incident angle and not straight-on.

"The tilt and distribution of stars in the stellar halo provide dramatic confirmation that our galaxy collided with another smaller galaxy 7-10 billion years ago," says Conroy.

Notably, so much time has passed since the GSE-Milky Way smash-up that the stellar halo stars would have been expected to dynamically settle into the classical, long-assumed spherical shape. The fact that they haven't likely speaks to the broader galactic halo, the team says. This dark matter-dominated structure is itself probably askew, and through its gravity, is likewise keeping the stellar halo off-kilter.

"The tilted stellar halo strongly suggests that the underlying dark matter halo is also tilted," says Conroy. "A tilt in the dark matter halo could have significant ramifications for our ability to detect dark matter particles in laboratories on Earth."

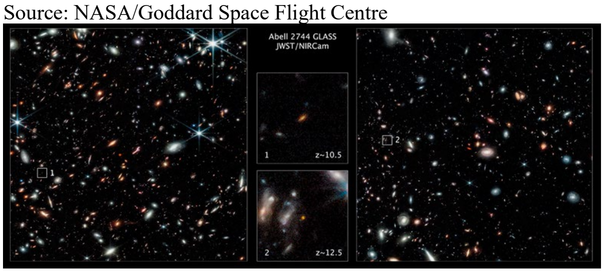
Conroy's latter point alludes to the multiple dark matter detector experiments now running and planned. These detectors could increase their chances of capturing an elusive interaction with dark matter if astrophysicists can adjudge where the substance is more heavily concentrated, galactically speaking. As Earth moves through the Milky Way, it will periodically encounter these regions of dense and higher-velocity dark matter particles, boosting odds of detection.

The discovery of the stellar halo's most plausible configuration stands to move many astrophysical investigations forward while filling in basic details about our place in the universe.

"These are such an intuitively interesting questions to ask about our galaxy: 'What does the galaxy look like?' and 'What does the stellar halo look like?'," says Han. "With this line of research and study in particular, we are finally answering those questions."

❖ NASA's Webb draws back curtain on universe's early galaxies

Date: November 17, 2022
Source: NASA/Goddard Space Flight Centre



Two of the farthest galaxies seen to date are captured in these Webb Space Telescope pictures of the outer regions of the giant galaxy cluster Abell 2744. The galaxies are not inside the cluster, but many billions of light-years farther behind it. The galaxy labelled (1) existed only 450 million years after the big bang. The galaxy labelled (2) existed 350 million years after the big bang. Both are seen really close in time to the big bang which occurred 13.8 billion years ago. These galaxies are tiny compared to our Milky Way, being just a few percent of its size, even the unexpectedly elongated galaxy labelled (1).
Credits: Science: NASA, ESA, CSA, Tommaso Treu (UCLA); Image Processing: Zolt G. Levay (STScI)
Download the full-resolution image from the Space Telescope Science Institute.

A few days after officially starting science operations, NASA's James Webb Space Telescope propelled astronomers into a realm of early galaxies, previously hidden beyond the grasp of all other telescopes until now. "Everything we see is new. Webb is showing us that there's a very rich universe beyond what we imagined," said Tommaso Treu of the University of California at Los Angeles, principal investigator on one of the Webb programs. "Once again the universe has surprised us. These early galaxies are very unusual in many ways."

Two research papers, led by Marco Castellano of the National Institute for Astrophysics in Rome, Italy, and Rohan Naidu of the Harvard-Smithsonian Centre for Astrophysics and the Massachusetts Institute of Technology in Cambridge, Massachusetts, have been published in the Astrophysical Journal Letters.

These initial findings are from a broader Webb research initiative involving two Early Release Science (ERS) programs: the Grism Lens-Amplified Survey from Space (GLASS), and the Cosmic Evolution Early Release Science Survey (CEERS).

With just four days of analysis, researchers found two exceptionally bright galaxies in the GLASS-JWST images. These galaxies existed approximately 450 and 350 million years after the big bang (with a redshift of approximately 10.5 and 12.5, respectively), though future spectroscopic measurements with Webb will help confirm.

"With Webb, we were amazed to find the most distant starlight that anyone had ever seen, just days after Webb released its first data," said Naidu of the more distant GLASS galaxy, referred to as GLASS-z12, which is believed to date back to 350 million years after big bang. The previous record holder is galaxy GN-z11, which existed 400 million years after the big bang (redshift 11.1), and was identified in 2016 by Hubble and Keck Observatory in deep-sky programs.

"Based on all the predictions, we thought we had to search a much bigger volume of space to find such galaxies," said Castellano.

"These observations just make your head explode. This is a whole new chapter in astronomy. It's like an archaeological dig, and suddenly you find a lost city or something you didn't know about. It's just staggering," added Paola Santini, fourth author of the Castellano et al. GLASS-JWST paper.

"While the distances of these early sources still need to be confirmed with spectroscopy, their extreme brightness's are a real puzzle, challenging our understanding of galaxy formation," noted Pascal Oesch at the University of Geneva in Switzerland, second author of the Naidu et al. paper.

The Webb observations nudge astronomers toward a consensus that an unusual number of galaxies in the early universe were much brighter than expected. This will make it easier for Webb to find even more early galaxies in subsequent deep sky surveys, say researchers.

"We've nailed something that is incredibly fascinating. These galaxies would have had to have started coming together maybe just 100 million years after the big bang. Nobody expected that the dark ages would have ended so early," said Garth Illingworth of the University of California at Santa Cruz, a member of the Naidu/Oesch team. "The primal universe would have been just one hundredth its current age. It's a sliver of time in the 13.8-billion-year-old evolving cosmos."

Erica Nelson of the University of Colorado, a member of the Naidu/Oesch team, noted that "our team was struck by being able to measure the shapes of these first galaxies; their calm, orderly disks question our understanding of how the first galaxies formed in the crowded, chaotic early universe." This remarkable discovery of compact disks at such early times was only possible because of Webb's much sharper images, in infrared light, compared to Hubble.

"These galaxies are very different than the Milky Way or other big galaxies we see around us today," said Treu.

Illingworth emphasized the two bright galaxies found by these teams have a lot of light. He said one option is that they could have been very massive, with lots of low-mass stars, like later galaxies. Alternatively, they could be much less massive, consisting of far fewer extraordinarily bright stars, known as Population III stars. Long theorized, they would be the first stars ever born, blazing at blistering temperatures and made up only of primordial hydrogen and helium -- before stars could later cook up heavier elements in their nuclear fusion furnaces. No such extremely hot, primordial stars are seen in the local universe.

"Indeed, the farthest source is very compact, and its colours seem to indicate that its stellar population is particularly devoid of heavy elements and could even contain some Population III stars. Only Webb spectra will

tell," said Adriano Fontana, second author of the Castellano *et al*. paper and a member of the GLASS-JWST team.
Present Webb distance estimates to these two galaxies are based on measuring their infrared colours. Eventually, follow-up spectroscopy measurements showing how light has been stretched in the expanding universe will provide independent verification of these cosmic yardstick measurements.

- Exploring the possibility of extra-terrestrial life living in caves

Date: November 16, 2022
Source: Northern Arizona University


A robot from NASA's Biologic and Resource Analog Investigations in Low Light Environments (BRAILLE) project travels inside a lava tube during field research at Lava Beds National Monument in California. Credit: J. G. Blank, NASA Ames Research Centre

Is there life in Martian caves?
It's a good question, but it's not the right question -- yet. An international collaboration of scientists led by NAU researcher Jut Wynne has dozens of questions we need asked and answered. Once we figure out how to study caves on the Moon, Mars and other planetary bodies, then we can return to that question.
Wynne, an assistant research professor of cave ecology, is the lead author of two related studies, both published in a special collection of papers on planetary caves by the *Journal of Geophysical Research Planets*. The first, "Fundamental Science and Engineering Questions in Planetary Cave Research," was done by an interdisciplinary team of 31 scientists, engineers and astronauts who produced a list of 198 questions that they, working with another 82 space and cave scientists and engineers, narrowed down to the 53 most important. Harnessing the knowledge of a considerable swath of the space science community, this work is the first study designed to identify the research and engineering priorities to advance the study of planetary caves. The team hopes their work will inform what will ultimately be needed to support robotic and human missions to a planetary cave -- namely on the Moon and/or Mars.
The second, "Planetary Caves: A Solar System View of Products and Processes," was born from the first study. Wynne realized there had been no effort to catalogue planetary caves across the solar system, which is another important piece of the big-picture puzzle. He assembled another team of planetary scientists to tackle that question.
"With the necessary financial investment and institutional support, the research and technological development required to achieve these necessary advancements over the next decade are attainable," Wynne said. "We now have what I hope will become two foundational papers that will help propel planetary cave research from an armchair contemplative exercise to robots probing planetary sub surfaces."

What we know about extra-terrestrial caves

There are a lot of them. Scientists have identified at least 3,545 potential caves on 11 different moons and planets throughout the solar system, including the Moon, Mars and moons of Jupiter and Saturn. Cave formation processes have even been identified on comets and asteroids. If the surrounding environment allows for access into the subsurface, that presents an opportunity for scientific discovery that's never been available before.
The discoveries in these caves could be massive. Caves may one day allow scientists to "peer into the depths" of these rocky and icy bodies, which will provide insights into how they were formed (but also can provide further insights into how Earth was formed). They could also, of course, hold secrets of life.
"Caves on many planetary surfaces represent one of the best environments to search for evidence of extinct or perhaps extant lifeforms," Wynne said. "For example, as Martian caves are sheltered from deadly surface radiation and violent windstorms, they are more likely to exhibit a more constant temperature regime compared to the surface, and some may even contain water ice. This makes caves on Mars one of the most important exploration targets in the search for life."

And it's not just finding life -- these same factors make caves good locations for astronaut shelters on Mars and the Moon when crewed missions are able to explore. "Radiation shielding will be essential for human exploration of the Moon and Mars," said Leroy Chiao, a retired astronaut, former commander of the International Space Station and co-author of the first paper. "One possible solution is to utilize caves for this purpose. The requirements for astronaut habitats, EVA suits and equipment should take cave exploration and development into consideration, for protection from both solar and galactic cosmic radiation."

What Earth can tell us about other planets

Wynne, whose primary research is in terrestrial caves, said planetary cave research has long been a parallel research question to the earthly variety for nearly two decades. Caves support unique ecosystems that are sometimes quite divorced from the surface ecosystem in the same area. Who's to say a cave on the Moon or Mars would not be similar? So, many questions he's investigated about caves on Earth, he's wondered how it could apply on other planets.

He's not the only one making the connection. Wynne has done multiple research projects with NASA to help advance detection technologies, and his modelling of cave habitats does not much care if a cave is terrestrial or extra-terrestrial. There are enough similarities in the cave environment to make reasonable predictions that will factor prominently into the selection of cave targets for exploration.

"Tellurian caves at depth are often characterized by complete darkness, a stable temperature approximating the average annual surface temperature, low to no air flow and a near-water-saturated atmosphere," he said. "The caves of other planetary bodies likely exhibit similar environmental conditions, but these will also be influenced by the surface conditions of the planetary body and the internal structure of the cave."

Keith Cowing, editor of SpaceRef.com and NASAWatch.com, said using the existing infrastructure of a planet's surface and subsurface may help humans get to other planets sooner than if we had to bring everything needed to survive with us.

"Humans have been living in caves for hundreds of thousands of years. Then they built their own when none were available," he said. "As such, it is only natural to assume that caves will offer similar utility as humanity expands to other worlds. While planet-wide terraforming may be an end goal, the use of large, pre-existing structures such as caves and lava tubes may be a more practical way to bootstrap the technology to the maturity needed to tackle the surface of an entire planet."

Where are we now?

While much of this research is forward-looking, there's also a need to consider what resources, research and support currently exist. Numerous robotic platforms and instrumentation suites are being tested, but the roadblock comes where it so often does -- the lack of funding. With sufficient support, a robotic exploration mission to a lunar or Martian cave could be possible in the next five to 10 years.

This research builds on past work to form a road map of sorts to move forward; Wynne sees it as a to-do list for that same process. The questions the scientists and engineers answered identify the tasks needed to prepare for that robotic exploration; it also looks even further ahead to the advancements needed in spacesuit technology, habitation modules and hardware that will enable humans to live and work safely underground on the Moon and Mars.

"This is an untapped area of inquiry in planetary science, and its importance in the search for life should not be overlooked," he said. "In our lifetime, it is quite possible that we will peer into underground Mars to address the age-old question, 'Does life exist beyond Earth?'"

- WALLABY builds an intergalactic map in the outback

Date: November 16, 2022
Source: International Centre for Radio Astronomy Research

Astronomical Society of Australia, the WALLABY (The Widefield ASKAP L-band Legacy All-sky Blind surveY) Pilot Survey will be sharing its first data release with the scientific community, helping us to better understand nearby galaxies and galactic clusters.

Hundreds of galaxies have been surveyed in Phase 1 of WALLABY, covering 180 square degrees of the observable sky -- the equivalent area of over 700 full moons.

Over the course of the survey a quarter of a million galaxies are expected to be catalogued, helping researchers measure the dark-matter distribution, internal motion of galaxies, and how these systems evolve and interact.

Lead author, Dr Tobias Westmeier, from The University of Western Australia node of the International Centre for Radio Astronomy Research (ICRAR/UWA) and the ARC Centre of Excellence for All Sky Astrophysics in 3 Dimensions (ASTRO 3D), said the data WALLABY collects will help us investigate the Universe at a scale we never could with just optical telescopes.

"If our own Milky Way is between us and the galaxy we're trying to observe, the sheer number of stars and dust makes it incredibly hard to see anything else," Dr Westmeier said.

"WALLABY isn't affected by these limitations. It's one of the great strengths of radio surveys; they can simply peer through all the stars and dust in our own Milky Way."

It's the first full 3D survey of this scale, with over 30 terabytes of data collected each eight-hour day from the ASKAP radio telescope in Western Australia's remote Mid-West region.

Co-author, WALLABY Project Scientist and Director of the Australia SKA Regional Centre, Dr Karen Lee-Waddell, said the project will show us where these galaxies really are in relation to one another in three-dimensional space, splitting up galaxies that appear clustered together but are millions of light years apart.

"WALLABY will enable us to directly map and detect hydrogen gas, the fuel for star-formation," said Dr Lee-Waddell.

"With this data, astronomers can accurately group galaxies to better understand how they affect each other when clustered together, providing insight on how galaxies form and change over time."

The WALLABY catalogue is expected to lead to many new observations and discoveries due to the sheer scale of the survey.

"Of the over 600 galaxies measured so far, many have not been previously catalogued at any other waveband and are considered new discoveries," said WALLABY's Principal Investigator and co-author Professor Lister Staveley-Smith (ICRAR/UWA).

"Over a dozen papers have been published so far describing new discoveries from these early observations."

CSIRO's Australia Telescope National Facility Science Program Director, Dr George Heald said these projects have been made possible through ASKAP's ability to collect data at a scale never seen before.

" bservatory is one of the most radio-quiet locations in the world, allowing projects like WALLABY to find narrow and faint astronomical signals without being swamped by radio interference," said Dr Heald.

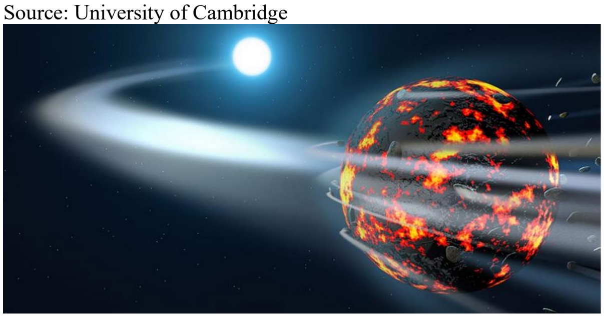
The international project is working with organisations such as AusSRC, the Canadian Astronomy Data Centre (led by the National Research Council of Canada), and CSIRO along with many international universities to help process and catalogue the data into a usable database for astronomers to access.

Professor Kristine Spekkens from Queens University and the Royal Military College of Canada is a co-author of the paper and an Executive Member of the WALLABY team.

"Astronomy in general, and WALLABY in particular, benefits from contributions from researchers around the world to make scientific breakthroughs," said Prof Spekkens.

- Study of 'polluted' white dwarfs finds that stars and planets grow together

Date: November 14, 2022
Source: University of Cambridge



A team of astronomers have found that planet formation in our young Solar System started much earlier than previously thought, with the building blocks of planets growing at the same time as their parent star.

A study of some of the oldest stars in the Universe suggests that the building blocks of planets like Jupiter and Saturn begin to form while a young star is growing. It had been thought that planets only form once a star has reached its final size, but new results, published in the journal *Nature Astronomy*, suggests that stars and planets 'grow up' together.

The research, led by the University of Cambridge, changes our understanding of how planetary systems, including our own Solar System, formed, potentially solving a major puzzle in astronomy.
"We have a pretty good idea of how planets form, but one outstanding question we've had is when they form: does planet formation start early, when the parent star is still growing, or millions of years later?" said Dr Amy Bonsor from Cambridge's Institute of Astronomy, the study's first author.
To attempt to answer this question, Bonsor and her colleagues studied the atmospheres of white dwarf stars -- the ancient, faint remnants of stars like our Sun -- to investigate the building blocks of planet formation. The study also involved researchers from the University of Oxford, the Ludwig-Maximilians-Universität in Munich, the University of Groningen and the Max Planck Institute for Solar System Research, Gottingen.
"Some white dwarfs are amazing laboratories, because their thin atmospheres are almost like celestial graveyards," said Bonsor.
Normally, the interiors of planets are out of reach of telescopes. But a special class of white dwarfs -- known as 'polluted' systems -- have heavy elements such as magnesium, iron, and calcium in their normally clean atmospheres.
These elements must have come from small bodies like asteroids left over from planet formation, which crashed into the white dwarfs and burned up in their atmospheres. As a result, spectroscopic observations of polluted white dwarfs can probe the interiors of those torn-apart asteroids, giving astronomers direct insight into the conditions in which they formed.
Planet formation is believed to begin in a protoplanetary disc -- made primarily of hydrogen, helium, and tiny particles of ices and dust -- orbiting a young star. According to the current leading theory on how planets form, the dust particles stick to each other, eventually forming larger and larger solid bodies. Some of these larger bodies will continue to accrete, becoming planets, and some remain as asteroids, like those that crashed into the white dwarfs in the current study.
The researchers analysed spectroscopic observations from the atmospheres of 200 polluted white dwarfs from nearby galaxies. According to their analysis, the mixture of elements seen in the atmospheres of these white dwarfs can only be explained if many of the original asteroids had once melted, which caused heavy iron to sink to the core while the lighter elements floated on the surface. This process, known as differentiation, is what caused the Earth to have an iron-rich core.
"The cause of the melting can only be attributed to very short-lived radioactive elements, which existed in the earliest stages of the planetary system but decay away in just a million years," said Bonsor. "In other words, if these asteroids were melted by something which only exists for a very brief time at the dawn of the planetary system, then the process of planet formation must kick off very quickly."
The study suggests that the early-formation picture is likely to be correct, meaning that Jupiter and Saturn had plenty of time to grow to their current sizes.
"Our study complements a growing consensus in the field that planet formation got going early, with the first bodies forming concurrently with the star," said Bonsor.
"Analyses of polluted white dwarfs tell us that this radioactive melting process is a potentially ubiquitous mechanism affecting the formation of all extrasolar planets.
"This is just the beginning -- every time we find a new white dwarf, we can gather more evidence and learn more about how planets form. We can trace elements like nickel and chromium and say how big an asteroid must have been when it formed its iron core. It's amazing that we're able to probe processes like this in exoplanetary systems."
Amy Bonsor is a Royal Society University Research Fellow at the University of Cambridge. The research was supported in part by the Royal Society, the Simons Foundation, and the European Research Council.

- Astronomers capitalize on early access to James Webb Space Telescope data

Advanced instruments aid in development of coherent picture of extragalactic nucleus

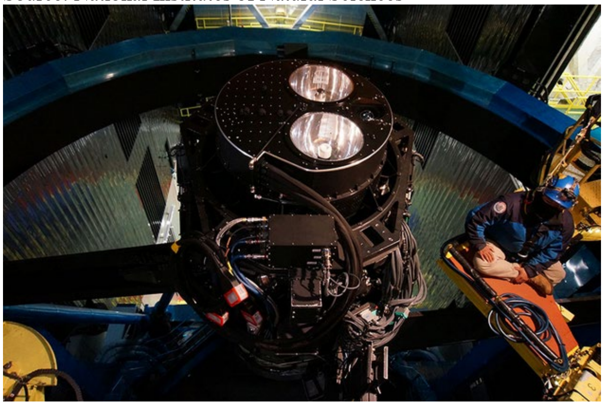
Date: November 14, 2022
Source: University of California – Irvine

First in line to receive data transmissions from the James Webb Space Telescope, a team of astronomers at the University of California, Irvine and other institutions is using the unprecedentedly clear observations to reveal the secret inner workings of galaxies.
In a paper published today in *The Astrophysical Journal Letters*, the researchers describe their examination of the nearby galaxy NGC 7469 with the JWST's ultrasensitive mid-infrared detection instruments. They conducted the most detailed analysis yet of the interactions between an active galactic nucleus dominated by a supermassive black hole and the star-forming galaxy regions surrounding it.
"What we are seeing in this system has been a surprise for us," said lead author Vivian U, UCI assistant research scientist in physics and astronomy and member of one of 13 JWST Early Release Science teams. "Viewing this galaxy face-on, we are able to see not only winds from the supermassive black hole blowing in our direction but also 'shock heating' of the gas induced by said winds very close to the central active galactic nucleus, which is something we had not expected to be able to discern so clearly."
U noted that shock heating happens when wind from a black hole in a galaxy's centre pushes on surrounding dense gas, creating a shock front that deposits energy into the interstellar medium. This effect could influence star formation in two opposing ways, she said. By compressing the gas into molecular form, it can foster the birth of new stars, or excessively strong feedback processes from the galactic wind can prevent birth by destroying stellar nurseries.
According to U, NGC 7469 is a Seyfert galaxy with an active centre hosting a supermassive black hole and a ring of star-forming regions. For decades, astronomers have tried to study the detailed dynamics of these systems, which make up about 10 percent of all galaxies, but dust -- commonly abundant at the centre of them -- has made that a challenge. The JWST gave U and her co-authors access to what lies behind the dust veil.
Using the telescope's 6.5-meter mirror and advanced suite of tools, including the Mid-Infrared Instrument, the researchers were able to map several key ionized and molecular gas emission lines that inform astronomers about the conditions of the interstellar medium -- the gas, dust and radiation that exist between star systems in a galaxy -- pinpointing star-forming regions within a starburst ring. They also detected a high-velocity outflow of ionized gas that's "blue shifted," meaning it's coming toward the observer versus traveling in the opposite direction.
"The newly realized capability of mid-infrared integral field spectroscopy from the JWST's Mid-Infrared Instrument now allows us to see not just what's there behind the dust but also how things are moving at very small scales that we couldn't previously see at these wavelengths," U said.
"We now have a more coherent picture -- at least in this system -- of how the active galactic nucleus is driving out gas and how that's impacting the surrounding material," she added. "We see definitive signs of the black hole-driven winds dumping energy out into the interstellar medium."
U said that a significant contributor to the roiling dynamics of NGC 7469 is the fact that it's merging with a second galaxy.
"The interaction with another galaxy means that galactic materials are being moved around as a result of tidal forces, and they file toward the centre of the galaxy system when angular momentum is lost. This process tends to make the galaxy centre very dusty," she explained. "That's why you need instruments like the ones aboard the JWST that allow us to peer through the dust and facilitate our understanding of the dusty cores of merging galaxies."
Today's publication is among the first in a series of papers from U and her collaborators that analyse data from the JWST Early Release Science Program No. 1328.
According to U, the spectacular imaging and spectroscopic data from the JWST offer an in-depth view of how galaxies evolve through the merging mechanism and enable her team to delve into the physics of star formation,

black hole growth and feedback in nearby merging galaxies.
Principal investigators include U, Lee Armus at the Infrared Processing & Analysis Centre at Caltech and Aaron Evans with the National Radio Astronomy Observatory in Virginia.
The study was supported by NASA and based on observations from the James Webb Space Telescope, which is jointly operated by NASA, the European Space Agency and the Canadian Space Agency

- 2400 new eyes on the sky to see cosmic rainbows

Date: November 11, 2022
Source: National Institutes of Natural Sciences

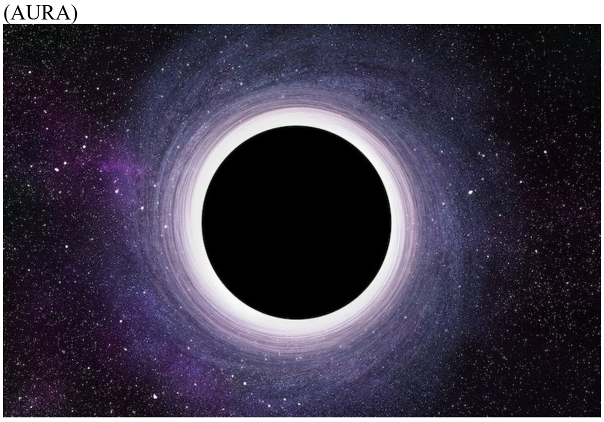


The new instrument for capturing cosmic rainbows mounted on the top of the Subaru Telescope. (Credit: Kavli IPMU)

The Subaru Telescope successfully demonstrated engineering first light with a new instrument that will use about 2400 fibreoptic cables to capture the light from heavenly objects. Full operation is scheduled to start around 2024. The ability to observe thousands of objects simultaneously will provide unprecedented amounts of data to fuel Big Data Astronomy in the coming decade.
In addition to cameras, astronomers also use instruments known as spectrographs to study celestial object. A spectrograph breaks the light from an object into its component colours, in other words it creates a precise rainbow. Studying the strengths of the different colours in the rainbow from an object can tell astronomers various details about the object such as its motion, temperature, and chemical composition.
This new instrument, called PFS (Prime Focus Spectrograph), breaks visible light rainbows into two components: the red side and the blue side. So, it might be more correct to refer to the data sets as half-rainbows. Combined with a third kind of detector which can see the infrared light invisible to humans, that makes one-and-a-half rainbows for an object studied with all three types of detectors.
Together with a widefield camera (HSC: Hyper Suprime-Cam), PFS will help launch the Subaru Telescope 2.0 project which will reveal the nature of dark matter and dark energy, structure formation in the Universe, and the physical processes of galaxy formation and evolution.

- Astronomers discover closest black hole to Earth

Gemini North telescope on Hawai'i reveals first dormant, stellar-mass black hole in our cosmic backyard
Date: November 4, 2022
Source: Association of Universities for Research in Astronomy (AURA)



Black hole illustration (stock image).
Credit: © vchalup / stock.adobe.com

Astronomers using the International Gemini Observatory, operated by NSF's NOIRLab, have discovered the closest-known black hole to Earth. This is the first unambiguous detection of a dormant stellar-mass black hole in the Milky Way. Its close proximity to Earth, a mere 1600 light-years away, offers an intriguing target of study to advance our understanding of the evolution of binary systems.
Black holes are the most extreme objects in the Universe. Supermassive versions of these unimaginably dense objects likely reside at the centres of all large galaxies. Stellar-mass black holes -- which weigh approximately five to 100 times the mass of the Sun -- are much more common, with an estimated 100 million in the Milky Way alone. Only a handful have been confirmed to date, however, and nearly all of these are 'active' -- meaning they shine brightly in X-rays as they consume material from a nearby stellar companion, unlike dormant black holes which do not.
Astronomers using the Gemini North telescope on Hawai'i, one of the twin telescopes of the International Gemini Observatory, operated by NSF's NOIRLab,

have discovered the closest black hole to Earth, which the researchers have dubbed Gaia BH1. This dormant black hole is about 10 times more massive than the Sun and is located about 1600 light-years away in the constellation Ophiuchus, making it three times closer to Earth than the previous record holder, an X-ray binary in the constellation of Monoceros. The new discovery was made possible by making exquisite observations of the motion of the black hole's companion, a Sun-like star that orbits the black hole at about the same distance as the Earth orbits the Sun.

"Take the Solar System, put a black hole where the Sun is, and the Sun where the Earth is, and you get this system," explained Kareem El-Badry, an astrophysicist at the Centre for Astrophysics | Harvard & Smithsonianand the Max Planck Institute for Astronomy, and the lead author of the paper describing this discovery. "While there have been many claimed detections of systems like this, almost all these discoveries have subsequently been refuted. This is the first unambiguous detection of a Sun-like star in a wide orbit around a stellar-mass black hole in our Galaxy."

Though there are likely millions of stellar-mass black holes roaming the Milky Way Galaxy, those few that have been detected were uncovered by their energetic interactions with a companion star. As material from a nearby star spirals in toward the black hole, it becomes superheated and generates powerful X-rays and jets of material. If a black hole is not actively feeding (i.e., it is dormant) it simply blends in with its surroundings.

"I've been searching for dormant black holes for the last four years using a wide range of datasets and methods," said El-Badry. "My previous attempts -- as well as those of others -- turned up a menagerie of binary systems that masquerade as black holes, but this is the first time the search has borne fruit."

The team originally identified the system as potentially hosting a black hole by analysing data from the European Space Agency's Gaia spacecraft. Gaia captured the minute irregularities in the star's motion caused by the gravity of an unseen massive object. To explore the system in more detail, El-Badry and his team turned to the Gemini Multi-Object Spectrograph instrument on Gemini North, which measured the velocity of the companion star as it orbited the black hole and provided precise measurement of its orbital period. The Gemini follow-up observations were crucial to constraining the orbital motion and hence masses of the two components in the binary system, allowing the team to identify the central body as a black hole roughly 10 times as massive as our Sun.

"Our Gemini follow-up observations confirmed beyond reasonable doubt that the binary contains a normal star and at least one dormant black hole," elaborated El-Badry. "We could find no plausible astrophysical scenario that can explain the observed orbit of the system that doesn't involve at least one black hole."

The team relied not only on Gemini North's superb observational capabilities but also on Gemini's ability to provide data on a tight deadline, as the team had only a short window in which to perform their follow-up observations.

"When we had the first indications that the system contained a black hole, we only had one week before the two objects were at the closest separation in their orbits. Measurements at this point are essential to make accurate mass estimates in a binary system," said El-Badry. "Gemini's ability to provide observations on a short timescale was critical to the project's success. If we'd missed that narrow window, we would have had to wait another year."

Astronomers' current models of the evolution of binary systems are hard-pressed to explain how the peculiar configuration of Gaia BH1 system could have arisen. Specifically, the progenitor star that later turned into the newly detected black hole would have been at least 20 times as massive as our Sun. This means it would have lived only a few million years. If both stars formed at the same time, this massive star would have quickly turned into a supergiant, puffing up and engulfing the other star before it had time to become a proper, hydrogen-burning, main-sequence star like our Sun.

It is not at all clear how the solar-mass star could have survived that episode, ending up as an apparently normal star, as the observations of the black hole binary indicate. Theoretical models that do allow for survival all predict that the solar-mass star should have ended up on a much tighter orbit than what is actually observed.

This could indicate that there are important gaps in our understanding of how black holes

form and evolve in binary systems, and also suggests the existence of an as-yet-unexplored population of dormant black holes in binaries.
"It is interesting that this system is not easily accommodated by standard binary evolution models," concluded El-Badry. "It poses many questions about how this binary system was formed, as well as how many of these dormant black holes there are out there."
"As part of a network of space- and ground-based observatories, Gemini North has not only provided strong evidence for the nearest black hole to date but also the first pristine black hole system, uncluttered by the usual hot gas interacting with the black hole," said NSF Gemini Program Officer Martin Still. "While this potentially augurs future discoveries of the predicted dormant black hole population in our Galaxy, the observations also leave a mystery to be solved -- despite a shared history with its exotic neighbour, why is the companion star in this binary system so normal?"
Gemini North observations were made as part of a director's discretionary time program (program id: GN-2022B-DD-202).
The International Gemini Observatory is operated by a partnership of six countries, including the United States through the National Science Foundation, Canada through the National Research Council of Canada, Chile through the Agencia Nacional de Investigación y Desarrollo, Brazil through the Ministério da Ciência, Tecnologia e Inovações, Argentina through the Ministerio de Ciencia, Tecnología e Innovación, and Korea through the Korea Astronomy and Space Science Institute. These Participants and the University of Hawaii, which has regular access to Gemini, each maintain a "National Gemini Office" to support their local users.