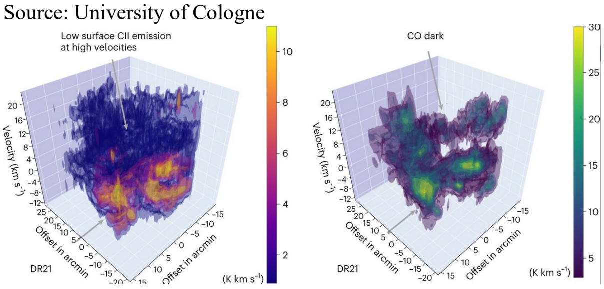
South Downs Mercury

The monthly circular of South Downs Astronomical Society
Issue: 573 – March 3rd 2023 Editor: Roger Burgess
Main Speaker Main Talk Hugh Allen - binary stars

Binary stars have a history of making waves in all branches of astronomy; the detections by the Laser Interferometer Gravitational-Wave Observatory (*LIGO*) are just the latest and maybe greatest example. The talk will use some of the speaker's own images and spectroscopic observations to illuminate the impact of binary stars on the history and science of astronomy.
I am an industrial chemist with a career in the printing ink industry, having studied Natural Sciences at Downing College, Cambridge. My interest in astronomy became a passion (some would say obsession) when my wife bought me a telescope in 2008. I started with visual observing and then astrophotography. In the last 9 years or so spectroscopy has become my main focus, the passion for which I share through talks and courses. I am Chairman of the Wells & Mendip Astronomers and a member of the Herschel Society in Bath.

- Astrophysics: Scientists observe high-speed star formation

Date: February 17, 2023
Source: University of Cologne

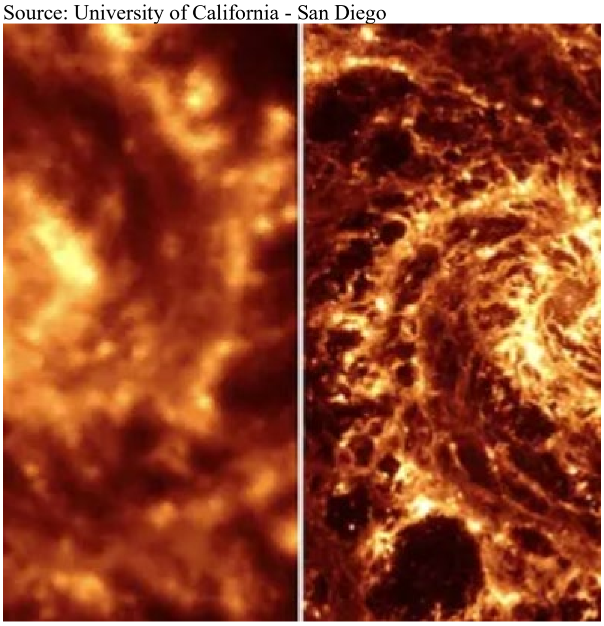


Even though SOFIA is no longer in operation, the data collected so far are essential for basic astronomical research because there is no longer an instrument that extensively maps the sky in this wavelength range (typically 60 to 200 micrometres). The now active James Webb Space Telescope observes in the infrared at shorter wavelengths and focuses on spatially small areas. Therefore, the analysis of the data collected by SOFIA is ongoing and continues to provide important insights – also regarding other star-forming regions: "In the list of FEEDBACK sources, there are other gas clouds in different stages of evolution, where we are now looking for the weak CII radiation at the peripheries of the clouds to detect similar interactions as in the Cygnus X region," Schneider concluded.
al standards. The results of the study 'Ionized carbon as a tracer for the assembly of interstellar clouds will appear in the next issue of *Nature Astronomy*.
The observations were carried out in an international project led by Dr Nicola Schneider at the University of Cologne and Prof Alexander Tielens at the University of Maryland as part of the FEEDBACK programme on board the flying observatory SOFIA (Stratospheric Observatory for Infrared Astronomy). The new findings modify previous perceptions that this specific process of star formation is quasi-static and quite slow. The dynamic formation process now observed would also explain the formation of particularly massive stars.
By comparing the distribution of ionized carbon, molecular carbon monoxide and atomic hydrogen, the team found that the shells of interstellar gas clouds are made of hydrogen and collide with each other at speeds of up to twenty kilometres per second. "This high speed compresses the gas into denser molecular regions where new, mainly massive stars form. We needed the CII observations to detect this otherwise 'dark' gas," said Dr Schneider. The observations show for the first time the faint CII radiation from the periphery of the clouds, which could not be observed before. Only SOFIA and its sensitive instruments were capable of detecting this radiation.
SOFIA was operated by NASA and the German Aerospace Centre (DLR) until September 2022. The observatory consisted of a converted Boeing 747 with a built-in 2.7-

metre telescope. It was coordinated by the German SOFIA Institute (DSI) and the Universities Space Research Association (USRA). SOFIA observed the sky from the stratosphere (above 13 kilometres) and covered the infrared region of the electromagnetic spectrum, just beyond what humans can see. The Boeing thus flew above most of the water vapour in the Earth's atmosphere, which otherwise blocks out infrared light. This allowed the scientists to observe a wavelength range that is not accessible from Earth. For the current results, the team used the upGREAT receiver installed on SOFIA in 2015 by the Max Planck Institute for Radio Astronomy in Bonn and the University of Cologne.
Even though SOFIA is no longer in operation, the data collected so far are essential for basic astronomical research because there is no longer an instrument that extensively maps the sky in this wavelength range (typically 60 to 200 micrometres). The now active James Webb Space Telescope observes in the infrared at shorter wavelengths and focuses on spatially small areas. Therefore, the analysis of the data collected by SOFIA is ongoing and continues to provide important insights – also regarding other star-forming regions: "In the list of FEEDBACK sources, there are other gas clouds in different stages of evolution, where we are now looking for the weak CII radiation at the peripheries of the clouds to detect similar interactions as in the Cygnus X region," Schneider concluded.

- ❖ A star is born: Nearby galaxies provide clues about star formation

Date: February 16, 2023
Source: University of California - San Diego



It is a popular notion that aside from large celestial objects like planets, stars and asteroids, outer space is empty. In fact, galaxies are filled with something called the interstellar medium (ISM) -- that is, the gas and dust that permeate the space in between those large objects. Importantly, under the right conditions, it is from the ISM that new stars are formed.
Now researchers from the University of California San Diego, in collaboration with a worldwide project team, have released their findings in a special issue of *The Astrophysical Journal Letters* dedicated to their work using advanced telescope images through the JWST Cycle 1 Treasury Program.
"With JWST, you can make incredible maps of nearby galaxies at very high resolution that provide amazingly detailed images of the interstellar medium," stated Associate Professor of Physics Karin Sandstrom who is a co-principal investigator on the project.
Although JWST can look at very distant galaxies, the ones Sandstrom's group studied are relatively close at about 30 million light years away, including one known as the Phantom Galaxy. Also known as M74 or NGC 628, astronomers have known of the Phantom Galaxy's existence since at least the 18th century.
Sandstrom, along with postdoctoral scholar Jessica Sutter and former postdoctoral scholar Jeremy Chastenet (now at University of Ghent), focused on a specific component of the ISM called polycyclic aromatic hydrocarbons (PAHs). PAHs are small particles of dust -- the size of a molecule -- and it's their small size that makes them so valuable to researchers.
When PAHs absorb a photon from a star, they vibrate and produce emission features that can be detected in the mid-infrared electromagnetic spectrum -- something that typically doesn't happen with larger dust grains from the ISM. The vibrational features of PAHs allow researchers to observe many important characteristics including size, ionization and structure.
This is something Sandstrom has been interested in since graduate school. "The Spitzer Space Telescope looked at the mid-infrared and that's what I used in my Ph.D. thesis. Since Spitzer was retired, we haven't had much access to the mid-infrared spectrum, but JWST is incredible," she stated. "Spitzer had a mirror that was 0.8 meters;

JWST's mirror is 6.5 meters. It's a huge telescope and it has amazing instruments. I've been waiting a very long time for this."

Even though PAHs are not by mass a big fraction of the overall ISM, they're important because they're easily ionized -- a process that can produce photoelectrons which heat the rest of the gas in the ISM. A better understanding of PAHs will lead to a better understanding of the physics of the ISM and how it operates. Astrophysicists are hopeful JWST can provide a view into how PAHs are formed, how they change and how they're destroyed.

Because PAHs are evenly distributed throughout the ISM, they allow researchers to see not just the PAHs themselves, but everything around them as well. Previous maps, such as ones taken by Spitzer, contained much less detail -- they essentially looked like galactic blobs. With the clarity JWST provides, astrophysicists can now see gas filaments and even "bubbles" blown by newly formed stars, whose intense radiation fields and resulting supernova evaporate the gas clouds around them.

To get observation time on JWST, the Cycle 1 Treasury Program team had to design observations that included details such as exposure length and filters. Once their submission was accepted, Space Telescope Science Institute, which is responsible for the science and mission operations for JWST, captures and processes the data. This program includes data from 19 galaxies in total.

The Cycle 1 Treasury Program is part of a bigger project called PHANGS (Physics at High Angular Resolution in Nearby GalaxieS). PHANGS studies star formation and the ISM using multi-wavelength images from the Atacama Large Millimetre Array (ALMA) and the Very Large Telescope, both in Chile. However, because the dense clouds in which star formation happens contain a lot of dust, it is difficult for optical light to penetrate to see what's happening inside. Using the mid-infrared spectrum allows researchers to use that same dust and its bright emission to get high-resolution, detailed images.

"One of the things I'm most excited about is now that we have this high-resolution tracer of the ISM, we can map all kinds of things, including the structure of the diffuse gas, which has to become denser and molecular for star formation to occur," said Sandstrom. "We can also map the gas surrounding newly formed stars where there is a lot of 'feedback' such as from supernova explosions. We really get to see the whole cycle of the ISM in a lot of detail. That is the core of how a galaxy is going to form stars."

This work is supported by Space Telescope Science Institute (JWST-GO-02107.006-A).

Further information:
https://iopscience.iop.org/collections/2041-8205_PHANGS-JWST-First-Results

❖ Tadpole playing around black hole

Date: February 16, 2023
Source: National Institutes of Natural Sciences

Artist's Impression of the "Tadpole" Molecular Cloud and the black hole at the gravitational centre of its orbit. Credit: Keio University

A peculiar cloud of gas, nicknamed the Tadpole due to its shape, appears to be revolving around a space devoid of any bright objects. This suggests that the Tadpole is orbiting a dark object, most likely a black hole 100,000 times more massive than the Sun. Future observations will help determine what is responsible for the shape and motion of the Tadpole.

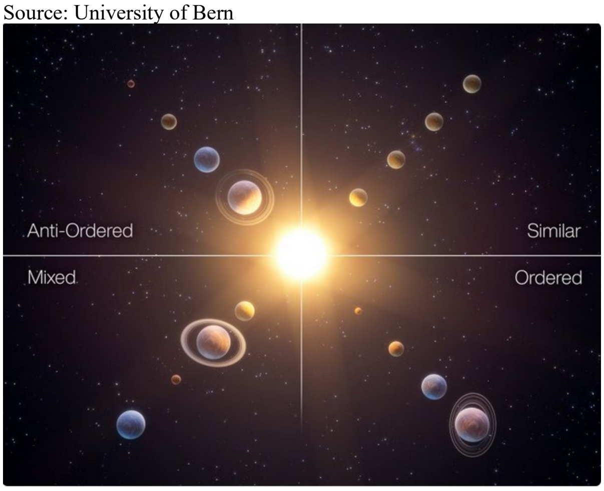
A team of Japanese researchers led by Miyuki Kaneko at Keio University used data from the James Clerk Maxwell Telescope, operated by the East Asian Observatory, and NAOJ's Nobeyama 45-m Radio Telescope to identify an unusual cloud of gas about 27,000 light-years away in the constellation Sagittarius. The curved "Tadpole" shape of the molecular gas cloud strongly suggests that it is being stretched as it orbits around a massive compact object. The only problem is, at the centre of the Tadpole's orbit, there are no bright objects which could be massive enough to gravitationally hold the Tadpole. The best candidate for this massive compact invisible object is a black hole.

Because black holes don't emit light, the only way to detect them is when they interact with other objects. This leaves astronomers in the dark about just how many black holes, and with what range of masses, might be lurking in the Milky Way.

Now the team plans to use ALMA (Atacama Large Millimetre/submillimetre Array) to search for faint signs of a black hole, or other object, at the gravitational centre of the Tadpole's orbit.

- Four classes of planetary systems

Date: February 14, 2023
Source: University of Bern



Artist's concept of 4 types of planetary systems, as recently categorized by scientists. Our own solar system is in the *Ordered* class. Turns out it's the rarest of the 4 groups studied so far. Image via UniBe/ © NCCR PlantS/ Tobias Stierli.

In our solar system, everything seems to be in order: The smaller rocky planets, such as Venus, Earth or Mars, orbit relatively close to our star. The large gas and ice giants, such as Jupiter, Saturn or Neptune, on the other hand, move in wide orbits around the sun. In two studies published in the scientific journal *Astronomy & Astrophysics*, researchers from the Universities of Bern and Geneva and the National Centre of Competence in Research (NCCR) PlanetS show that our planetary system is quite unique in this respect.

Like peas in a pod

"More than a decade ago, astronomers noticed, based on observations with the then ground-breaking Kepler telescope, that planets in other systems usually resemble their respective neighbours in size and mass – like peas in a pod," says study lead author Lokesh Mishra, researcher at the University of Bern and Geneva, as well as the NCCR PlanetS. But for a long time, it was unclear whether this finding was due to limitations of observational methods. "It was not possible to determine whether the planets in any individual system were similar enough to fall into the class of the 'peas in a pod' systems, or whether they were rather different – just like in our solar system," says Mishra. Therefore, the researcher developed a framework to determine the differences and similarities between planets of the same systems. And in doing so, he discovered that there are not two, but four such system architectures.

Four classes of planetary systems

"We call these four classes 'similar', 'ordered', 'anti-ordered' and 'mixed'," says Mishra. Planetary systems in which the masses of neighbouring planets are similar to each other, have similar architecture. Ordered planetary systems are those, in which the mass of the planets tends to increase with distance from the star – just as in our solar system. If, on the other hand, the mass of the planets roughly decreases with distance from the star, researchers speak of an anti-ordered architecture of the system. And mixed architectures occur, when the planetary masses in a system vary greatly from planet to planet.

"This framework can also be applied to any other measurements, such as radius, density or water fractions," says study co-author Yann Alibert, Professor of Planetary Science at the University of Bern and the NCCR PlanetS. "Now, for the first time, we have a tool to study planetary systems as a whole and compare them with other systems."

The findings also raise questions: Which architecture is the most common? Which factors control the emergence of an architecture type? Which factors do not play a role? Some of these, the researchers can answer.

A bridge spanning billions of years

"Our results show that 'similar' planetary systems are the most common type of architecture. About eight out of ten planetary systems around stars visible in the night sky have a 'similar' architecture," says Mishra. "This also explains why evidence of this architecture was found in the first few months of the Kepler mission." What surprised the team was that the "ordered" architecture – the one that also includes the solar system – seems to be the rarest class.

According to Mishra, there are indications that both the mass of the gas and dust disk from which the planets emerge, as well as the abundance of heavy elements in the respective star play a role. "From rather small, low-mass disks and stars with few heavy elements, 'similar' planetary systems emerge. Large, massive disks with many heavy elements in the star give rise to more ordered and anti-ordered systems. Mixed systems emerge from medium-sized disks. Dynamic interactions

between planets – such as collisions or ejections – influence the final architecture," Mishra explains.
"A remarkable aspect of these results is that it links the initial conditions of planetary and stellar formation to a measurable property: the system architecture. Billions of years of evolution lie in between them. For the first time, we have succeeded in bridging this huge temporal gap and making testable predictions. It will be exciting to see if they will hold up," Alibert concludes.

- HETDEX reveals galaxy gold mine in first large survey

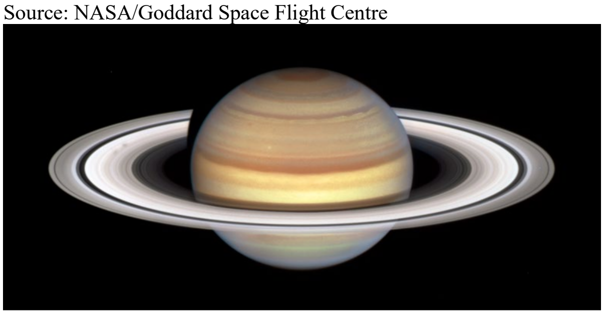
TACC systems support catalogue release of over 200,000 new star and galaxy locations
Date: February 9, 2023
Source: University of Texas at Austin, Texas Advanced Computing Centre

Astronomers have barely scratched the surface of mapping the nearly endless stars and galaxies of the heavens. Using supercomputers, researchers with The University of Texas at Austin have has now revealed the locations of more than 200,000 new astronomical objects. Their goal is to map even more and use that knowledge to predict the ultimate fate of the universe.
The Hobby-Eberly Telescope Dark Energy Experiment (HETDEX) has scanned the dark skies of the Davis Mountains in West Texas since 2017 with a keen eye towards capturing spectroscopic data on Lyman-alpha frequency light from neutral hydrogen emission in galaxies over 10 billion light years away. These galaxies emit a signature wavelength of light from hydrogen that signals to astronomers the intense creation of new stars.
The HETDEX collaboration involves a large team including astronomers, engineers, technicians, and graduate students from six academic institutions in the United States and Germany.
For the first time, the researchers have catalogued astronomical objects -- mapping over 51,863 Lyman-alpha-emitting galaxies at high redshift; 123,891 star forming galaxies at lower redshift; 5,274 non-emission line galaxies at low redshift; and 4,976 active galactic nuclei (AGN) -- bright spots that signal the presence of black holes.
The paper describing the catalogue is published February 2023 in *The Astrophysical Journal.*
"We've just exploded in terms of the number of redshifts catalogued for the first time," said study co-author Erin Mentuch Cooper, a research scientist at The University of Texas at Austin (UT Austin). Cooper is the data manager for the HETDEX project.
"There is a gold mine of astronomy exploration in the HETDEX catalogue. That's what I love about it," said study co-author Karl Gebhardt, the Herman and Joan Suit Professor in Astronomy, College of Natural Sciences, UT Austin. Gebhardt is project scientist and principal investigator of HETDEX.
A star's redshift tells astronomers how fast a star is moving away from the Earth because its frequency, akin to its colour, gets lower as it moves away, much like the horn of a train as it passes by.
The faster a star moves away, the farther away it is. That relationship between speed and distance, called Hubble's Law, can pin down a galaxy's location and allows astronomers to create a 3D map of over 200,000 stars and galaxies with HETDEX.
"This is only a small percentage of what we will find, but it's a good start. Ultimately, HETDEX aims to map one million red-shifted galaxies," Cooper said.
HETDEX is unique from previous large sky surveys because it's a non-targeted survey, blanketing the sky and collecting spectra from the 35,000 fibre optic cables of the Visible Integral Field Replicable Unit Spectrograph (VIRUS).
VIRUS takes starlight from distant galaxies and splits the light into its component colours like a prism does. HETDEX tiles the sky, collecting 35,000 spectra in a moon-sized swath of sky and moving from spot to spot. It collects about 500-600 hours of observations each year for its survey data.
"We have the largest spectroscopic instrument on the planet, and we're doing one of the longest surveys in terms of time," Gebhardt said. "To analyse this data, we need the fastest computer we can get our hands on, and that's where TACC comes in. TACC does all the data storage and all the data analysis for this giant survey."
The data from the telescope goes straight to the TACC Corral data storage system via high-speed lines at 100 Gigabits/second.
"TACC has worked hard with us to streamline our system, and it's just working fantastically. We can process years of data in a couple of

days, maybe a week of time on TACC systems. And we do it multiple times because we keep adjusting and improving our methods," Gebhardt added.
HETDEX used the Maverick and Stampede2 supercomputers of the Texas Advanced Computing Centre, a leading academic supercomputing centre at UT Austin. Stampede2 is funded by the National Science Foundation as a shared resource for thousands of scientists across the US. They helped process and analyse about 60 terabytes of image data on TACC's Corral system.
What's more, Cooper and colleagues have worked with TACC to create JupyterHub public access to the data.
"Anyone with any academic credentials can get a TACC account and go on through a web browser to access our data. We're going to let them access all of our data. This is just the catalogue right now. But the future is going to offer a legacy potential of the science from HETDEX. TACC is helping setting that up," Cooper said.
One interesting highlight from the catalogue is the identification of an active galactic nuclei (AGN) with strong Lyman-alpha light emission. Gebhadt co-authored a study led by UT Austin astronomy post-doctoral researcher Chenxu Liu, published November 2022 in The Astrophysical Journal. It presents intriguing evidence of a black hole without a surrounding host galaxy.
"This is what I call 'naked black holes,'" Gebhardt said. "Nothing confirmed yet, but we suspect these could be out there. Only a survey like HETDEX will be able to find these."
The science generated from HETDEX adds to the bigger picture of understanding the expansion of the entire universe, unexpectedly growing much faster than expected based on precise observations from the Hubble Space Telescope in 2019 of supernovae that act like a cosmic yardstick.
The Holy Grail for HETDEX is an accurate measure of the Universe expansion rate 10 billion years ago that will reveal the physical model for dark energy.
Astronomers are at odds over how to explain the measure of the current expansion rate. Understanding it could require a modification in the theory of gravity, or a change in the fundamental Big Bang theory. It might be the handiwork of an undiscovered particle.
A precise value of the expansion rate early in the Universe can be compared to the expansion rate today. This comparison can determine if the Universe will continue to expand forever, or will someday collapse on itself many billions of years from now.
"The whole point of the HETDEX project is to measure the expansion of the universe," Gebhardt said.
"This new catalogue adds valuable data in finally answering the 'million galaxy' question, which is something the HETDEX Collaboration is working very hard on in the coming year. But there's a bigger picture here, and that's what we give back to the community, not just to the scientists around the world but the general community. We wouldn't be able to do this work without the supercomputing resources and experts at TACC, through allowing us the computing power to run many analyses of the data and continue to improve the process."

- Hubble captures the start of a new spoke season at Saturn

Date: February 9, 2023
Source: NASA/Goddard Space Flight Centre



NASA's Hubble Space Telescope has observation time devoted to Saturn each year, thanks to the Outer Planet Atmospheres Legacy (OPAL) program, and the dynamic gas giant planet always shows us something new. This latest image heralds the start of Saturn's "spoke season" with the appearance of two smudgy spokes in the B ring, on the left in the image. The shape and shading of spokes vary – they can appear light or dark, depending on the viewing angle, and sometimes appear more like blobs than classic radial spoke shapes, as seen here. The ephemeral features don't last long, but as the planet's autumnal equinox approaches on May 6, 2025, more will appear. Scientists will be looking for clues to explain the cause and nature of the spokes. It's suspected they are ring material that is temporarily charged and levitated by interaction between Saturn's magnetic field and the solar wind, but this hypothesis has not been confirmed. Credits: NASA, ESA, and Amy Simon (NASA-GSFC); Image Processing: Alyssa Pagan (STScI)

New images of Saturn from NASA's Hubble Space Telescope herald the start of the planet's "spoke season" surrounding its equinox, when enigmatic features appear across its rings. The cause of the spokes, as well as their seasonal variability, has yet to be fully explained by planetary scientists.
Like Earth, Saturn is tilted on its axis and therefore has four seasons, though because of Saturn's much larger orbit, each season lasts approximately seven Earth years. Equinox

occurs when the rings are tilted edge-on to the Sun. The spokes disappear when it is near summer or winter solstice on Saturn. (When the Sun appears to reach either its highest or lowest latitude in the northern or southern hemisphere of a planet.) As the autumnal equinox of Saturn's northern hemisphere on May 6, 2025, draws near, the spokes are expected to become increasingly prominent and observable.

The suspected culprit for the spokes is the planet's variable magnetic field. Planetary magnetic fields interact with the solar wind, creating an electrically charged environment (on Earth, when those charged particles hit the atmosphere this is visible in the northern hemisphere as the aurora borealis, or northern lights). Scientists think that the smallest, dust-sized icy ring particles can become charged as well, which temporarily levitates those particles above the rest of the larger icy particles and boulders in the rings.

The ring spokes were first observed by NASA's Voyager mission in the early 1980s. The transient, mysterious features can appear dark or light depending on the illumination and viewing angles.

"Thanks to Hubble's OPAL program, which is building an archive of data on the outer solar system planets, we will have longer dedicated time to study Saturn's spokes this season than ever before," said NASA senior planetary scientist Amy Simon, head of the Hubble Outer Planet Atmospheres Legacy (OPAL) program.

Saturn's last equinox occurred in 2009, while NASA's Cassini spacecraft was orbiting the gas giant planet for close-up reconnaissance. With Cassini's mission completed in 2017, and the Voyager spacecrafts long gone, Hubble is continuing the work of long-term monitoring of changes on Saturn and the other outer planets.

"Despite years of excellent observations by the Cassini mission, the precise beginning and duration of the spoke season is still unpredictable, rather like predicting the first storm during hurricane season," Simon said.

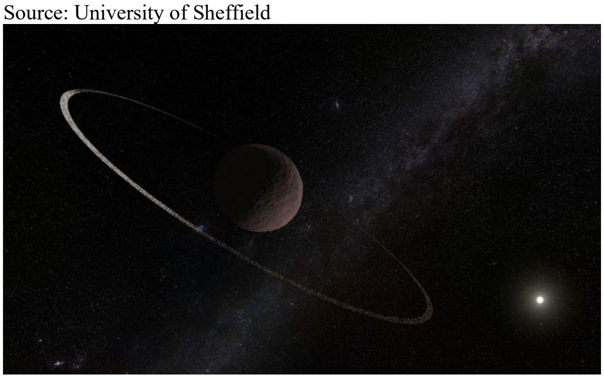
While our solar system's other three gas giant planets also have ring systems, nothing compares to Saturn's prominent rings, making them a laboratory for studying spoke phenomena. Whether spokes could or do occur at other ringed planets is currently unknown. "It's a fascinating magic trick of nature we only see on Saturn -- for now at least," Simon said.

Hubble's OPAL program will add both visual and spectroscopic data, in wavelengths of light from ultraviolet to near-infrared, to the archive of Cassini observations. Scientists are anticipating putting these pieces together to get a more complete picture of the spoke phenomenon, and what it reveals about ring physics in general.

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 conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy, in Washington, D.C.

- A new ring system discovered in our Solar System

Date: February 8, 2023
Source: University of Sheffield



Credit: Instituto de Astrofísica de Andalucia

Scientists have discovered a new ring system around a dwarf planet on the edge of the Solar System. The ring system orbits much further out than is typical for other ring systems, calling into question current theories of how ring systems are formed.

The ring system is around a dwarf planet, named Quaoar, which is approximately half the size of Pluto and orbits the Sun beyond Neptune.

The discovery, published in *Nature*, was made by an international team of astronomers using HiPERCAM -- an extremely sensitive high-speed camera developed by scientists at the University of Sheffield which is mounted on the world's largest optical telescope, the 10.4 metre diameter Gran Telescopio Canarias (GTC) on La Palma.

The rings are too small and faint to see directly in an image. Instead, the researchers made their discovery by observing an occultation, when the light from a background

star was blocked by Quaoar as it orbits the Sun. The event lasted less than a minute, but was unexpectedly preceded and followed by two dips in light, indicative of a ring system around Quaoar.
Ring systems are relatively rare in the Solar System -- as well as the well-known rings around the giant planets Saturn, Jupiter, Uranus and Neptune, only two other minor planets possess rings -- Chariklo and Haumea. All of the previously known ring systems are able to survive because they orbit close to the parent body, so that tidal forces prevent the ring material from accreting and forming moons.
What makes the ring system around Quaoar remarkable is that it lies at a distance of over seven planetary radii -- twice as far out as what was previously thought to be the maximum radius according to the so-called `Roche limit', which is the outer limit of where ring systems were thought to be able to survive. For comparison, the main rings around Saturn lie within three planetary radii. This discovery has therefore forced a rethink on theories of ring formation.
Professor Vik Dhillon, co-author of the study from the University of Sheffield's Department of Physics and Astronomy, said: "It was unexpected to discover this new ring system in our Solar System, and it was doubly unexpected to find the rings so far out from Quaoar, challenging our previous notions of how such rings form. The use of our high-speed camera -- HiPERCAM -- was key to this discovery as the event lasted less than one minute and the rings are too small and faint to see in a direct image.
"Everyone learns about Saturn's magnificent rings when they're a child, so hopefully this new finding will provide further insight into how they came to be."
The study involved 59 academics from all over the world, led by the Federal University of Rio de Janeiro in Brazil. The research was partly funded by the Science and Technology Facilities Council (STFC) and included six UK universities -- Sheffield, Edinburgh, St Andrews, Warwick, Birmingham, and the Open University.

- Footprints of galactic immigration uncovered in Andromeda galaxy

The Dark Energy Spectroscopic Instrument reveals compelling evidence of a mass migration of stars into a galaxy other than the Milky Way

Date: February 8, 2023
Source: Association of Universities for Research in Astronomy (AURA)

A team of researchers led by astronomers at NSF's NOIRLab has uncovered striking new evidence for a mass migration of stars into the Andromeda Galaxy. Intricate patterns in the motions of stars reveal an immigration history very similar to that of the Milky Way. The new results were obtained with the DOE's Dark Energy Spectroscopic Instrument on the Nicholas U. Mayall 4-meter Telescope at Kitt Peak National Observatory, a Program of NSF's NOIRLab. Credit: KPNO/NOIRLab/AURA/NSF/Local Group Survey Team/T.A. Rector (University of Alaska Anchorage)/D. de Martin/M. Zamani

Over the course of billions of years, galaxies grow and evolve by forging new stars and merging with other galaxies through aptly named "galactic immigration" events. Astronomers try to uncover the histories of these immigration events by studying the motions of individual stars throughout a galaxy and its extended halo of stars and dark matter. Such cosmic archaeology, however, has only been possible in our own galaxy, the Milky Way, until now.
An international team of researchers has uncovered striking new evidence of a large galactic immigration event in the Andromeda Galaxy, the Milky Way's nearest large galactic neighbour. The new results were made with the DOE's Dark Energy Spectroscopic Instrument (DESI) on the Nicholas U. Mayall 4-meter Telescope at Kitt Peak National Observatory, a Program of NSF's NOIRLab.
By measuring the motions of nearly 7500 stars in the inner halo of the Andromeda Galaxy, also known as Messier 31 (M31), the team discovered tell-tale patterns in the positions and motions of stars that revealed how these stars began their lives as part of another galaxy that merged with M31 about 2 billion years ago. While such patterns have

long been predicted by theory, they have never been seen with such clarity in any galaxy.

"Our new observations of the Milky Way's nearest large galactic neighbour, the Andromeda Galaxy, reveal evidence of a galactic immigration event in exquisite detail," explained Arjun Dey, astronomer at NSF's NOIRLab and the lead author of the paper presenting this research. "Although the night sky may seem unchanging, the Universe is a dynamic place. Galaxies like M31 and our Milky Way are constructed from the building blocks of many smaller galaxies over cosmic history. "

"We have never before seen this so clearly in the motions of stars, nor had we seen some of the structures that result from this merger," said Sergey Koposov, an astrophysicist at the University of Edinburgh and co-author of the paper. "Our emerging picture is that the history of the Andromeda Galaxy is similar to that of our own Galaxy, the Milky Way. The inner halos of both galaxies are dominated by a single immigration event."

This research sheds light on not only the history of our galactic neighbours but also the history of our own galaxy. Most of the stars in the Milky Way's halo were formed in another galaxy and later migrated into our own in a galactic merger 8-10 billion years ago. Studying the relics of a similar, but more recent, galaxy merger in M31 gives astronomers a window onto one of the major events in the Milky Way's past.

To trace the history of migration in M31, the team turned to DESI. DESI was constructed to map tens of millions of galaxies and quasars in the nearby Universe in order to measure the effect of dark energy on the expansion of the Universe. It is the most powerful multi-object survey spectrograph in the world, and is capable of measuring the spectra of more than 100,000 galaxies a night. DESI's world-class capabilities can also be put to use closer to home, however, and the instrument was crucial to the team's survey of M31.

"This science could not have been done at any other facility in the world. DESI's amazing efficiency, throughput, and field of view make it the best system in the world to carry out a survey of the stars in the Andromeda Galaxy," said Dey. "In only a few hours of observing time, DESI was able to surpass more than a decade of spectroscopy with much larger telescopes."

Even though the Mayall Telescope was completed 50 years ago (it achieved first light in 1973), it remains a world-class astronomical facility thanks to continued upgrades and state-of-the-art instrumentation. "Fifty years sounds like a long time, and naïvely one might think that's the natural lifetime of a facility," said co-author Joan R. Najita, also at NOIRLab. "But with renewal and reuse, a venerable telescope like the Mayall can continue to make amazing discoveries despite being relatively small by today's standards."

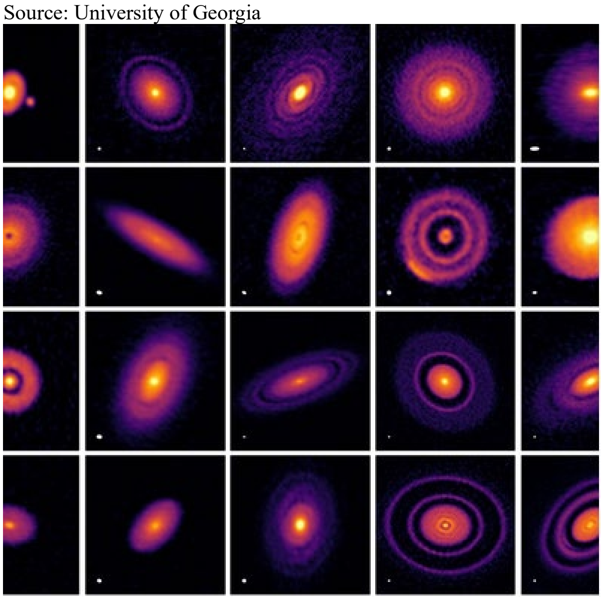
The research was carried out in collaboration with two Harvard University undergraduates, Gabriel Maxemin and Joshua Josephy-Zack, who connected with the project through the Radcliffe Institute for Advanced Study. Najita was a Radcliffe Fellow from 2021 to 2022.

The team now plans to use the unparalleled capabilities of DESI and the Mayall Telescope to explore more of M31's outlying stars, with the aim of revealing its structure and immigration history in unprecedented detail.

"It's amazing that we can look out at the sky and read billions of years of another galaxy's history as written in the motions of its stars -- each star tells part of the story," concluded Najita. "Our initial observations exceeded our wildest expectations and we are now hoping to conduct a survey of the entire M31 halo with DESI. Who knows what new discoveries await!"

- ❖ Researchers focus AI on finding exoplanets

Date: February 7, 2023
Source: University of Georgia



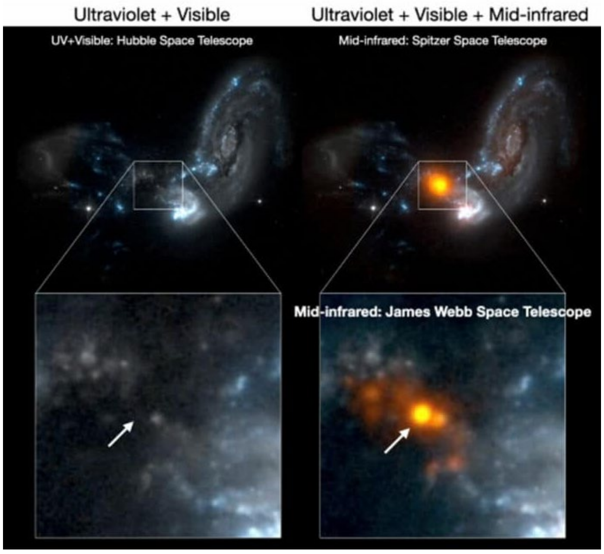
New research from the University of Georgia reveals that artificial intelligence can be used to find planets outside of our solar system.
The recent study demonstrated that machine learning can be used to find exoplanets, information that could reshape how scientists detect and identify new planets very far from Earth.
"One of the novel things about this is analysing environments where planets are still forming," said Jason Terry, doctoral student in the UGA Franklin College of Arts and Sciences department of physics and astronomy and lead author on the study. "Machine learning has rarely been applied to the type of data we're using before, specifically for looking at systems that are still actively forming planets."
The first exoplanet was found in 1992, and though more than 5,000 are known to exist, those have been among the easiest for scientists to find. Exoplanets at the formation stage are difficult to see for two primary reasons. They are too far away, often hundreds of lights years from Earth, and the discs where they form are very thick, thicker than the distance of the Earth to the sun. Data suggests the planets tend to be in the middle of these discs, conveying a signature of dust and gases kicked up by the planet.
The research showed that artificial intelligence can help scientists overcome these difficulties.
"This is a very exciting proof of concept," said Cassandra Hall, assistant professor of astrophysics, principal investigator of the Exoplanet and Planet Formation Research Group, and co-author on the study. "The power here is that we used exclusively synthetic telescope data generated by computer simulations to train this AI, and then applied it to real telescope data. This has never been done before in our field, and paves the way for a deluge of discoveries as James Webb Telescope data rolls in."
The James Webb Space Telescope, launched by NASA in 2021, has inaugurated a new level of infrared astronomy, bringing stunning new images and reams of data for scientists to analyse. It's just the latest iteration of the agency's quest to find exoplanets, scattered unevenly across the galaxy. The Nancy Grace Roman Observatory, a 2.4-meter survey telescope scheduled to launch in 2027 that will look for dark energy and exoplanets, will be the next major expansion in capability -- and delivery of information and data -- to comb through the universe for life.
The Webb telescope supplies the ability for scientists to look at exoplanetary systems in an extremely bright, high resolution, with the forming environments themselves a subject of great interest as they determine the resulting solar system.
"The potential for good data is exploding, so it's a very exciting time for the field," Terry said.

New analytical tools are essential

Next-generation analytical tools are urgently needed to greet this high-quality data, so scientists can spend more time on theoretical interpretations rather than meticulously combing through the data and trying to find tiny little signatures.
"In a sense, we've sort of just made a better person," Terry said. "To a large extent the way we analyse this data is you have dozens, hundreds of images for a specific disc and you just look through and ask 'is that a wiggle?' then run a dozen simulations to see if that's a wiggle and … it's easy to overlook them -- they're really tiny, and it depends on the cleaning, and so this method is one, really fast, and two, its accuracy gets planets that humans would miss."
Terry says this is what machine learning can already accomplish -- improve on human capacity to save time and money as well as efficiently guide scientific time, investments and new proposals.
"There remains, within science and particularly astronomy in general, scepticism about machine learning and of AI, a valid criticism of it being this black box -- where you have hundreds of millions of parameters and somehow you get out an answer. But we think we've demonstrated pretty strongly in this work that machine learning is up to the task. You can argue about interpretation. But in this case, we have very concrete results that demonstrate the power of this method."
The research team's work is designed to develop a concrete foundation for future applications on observational data, demonstrating the method's effectiveness by using simulation observations.

- 'Engine' of luminous merging galaxies pinpointed for the first time

Date: February 6, 2023
Source: Hiroshima University



JWST pinpoints the ‘invisible’ engine that powers the galaxies in the middle of a collision Astronomers from an international team have used the James Webb Space Telescope to reveal, for the first time, the exact location of the source powering colliding galaxies. Curiously, this source lies outside of the main parts of the galaxies and is not visible at all in the ultraviolet or visible light observed with the Hubble Space Telescope. (Hanae Inami/Hiroshima University)

Roughly 500 million light-years away, near the constellation Delphinus, two galaxies are colliding. Known as merging galaxy IIZw096, this luminous phenomenon is obscured by cosmic dust, but researchers first identified a bright, energetic source of light 12 years ago. Now, with a more advanced telescope -- the James Webb Space Telescope that started its observations in July 2022 -- the team has pinpointed the precise location of what they have dubbed the "engine" of the merging galaxy.

They published their results on Nov. 15, 2022, in *The Astrophysical Journal Letters*.

"The James Webb Space Telescope has brought us completely new views of the universe thanks to it having the highest ever spatial resolution and sensitivity in the infrared," said corresponding author Hanae Inami, assistant professor at Hiroshima University's Hiroshima Astrophysical Science Centre. "We wanted to find the 'engine' that powers this merging galaxy system. We knew that this source was deeply hidden by cosmic dust, so we could not use visible or ultraviolet light to find it. Only in the mid-infrared, observed with the James Webb Space Telescope, do we now see that this source outshines everything else in these merging galaxies."

As galaxies merge, their stars, planets and other constituents can smash into one another, the debris serving as fodder for new celestial episodes. Most of these galactic collisions only emit infrared light, which has longer wavelengths than light visible to humans and is beyond the scope of human perception. In 2010, using the Spitzer Space Telescope, the same team found that the merging system was dominated by bright infrared emission. The researchers could measure the power of the engine -- the source of such brightness -- but could not identify its exact location due to the telescope's limited resolution.

With the James Webb Space Telescope, they found that this engine is responsible for the bulk of the mid-infrared emission, which accounts for up to 70% of the total infrared emission of the system. They also found that the source has a radius no larger than 570 light years -- a tiny fraction of the size of the merging system, which is about 65,000 light years across. This indicates that the energy is confined to a small space, according to co-author Thomas Bohn at Hiroshima University.

"It is intriguing that this compact source, far from the galactic centres, dominates the infrared luminosity of the system," Bohn said. According to Bohn, this source makes a significant contribution to the merging galaxies despite lying in the outskirts, like a speck of pepper on the white of a fried egg.

"We want to know what powers this source: is it a starburst or a massive black hole?" Inami asked. "We will use infrared spectra taken with the James Webb Space Telescope to investigate this. It is also unusual that the 'engine' lies outside of the main parts of the merging galaxies, so we will explore how this powerful source ended up there."

Co-author Jason Surace of the California Institute of Technology said that the finding supports more recently developed understandings of the universe and how it changes.

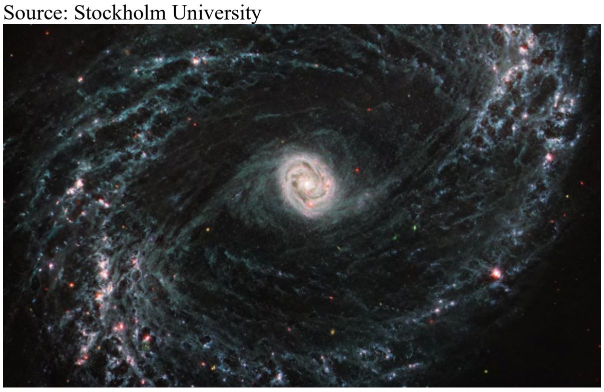
"The last few decades, driven by new, mostly space-based observations in the infrared, have shown that the universe is a surprisingly dynamic and violently changing place," Surace said. "In times past, it was thought that the galaxies -- the largest things we knew of -- simply spun essentially unchanging, like celestial temples in the heavens."

In addition to identifying the location of the engine, the researchers found 12 "clumps" of light. While some of these were previously revealed by the near-infrared capabilities of the Hubble Space Telescope, five were newly detected with the James Webb Space Telescope. These, Inami said, are emitting mid-infrared colours that suggest they are forming stars.

"The James Webb Space Telescope mid-infrared imaging described in this paper revealed a hidden aspect of the merging galaxy IIZw096 and opened a door towards identifying heavily dust-obscured sources which cannot be found at shorter wavelengths," Inami said. "Future planned spectroscopic observations of IIZw096 will provide additional information on the nature of the dust, ionized gas, and warm molecular gas in and around the disturbed region of this luminous merging galaxy."
This work was conducted as a part of the JWST Early Release Science (ERS) Program of the Great Observatory All-sky LIRG Survey (GOALS) project, which targets four local merging galaxies, including IIZw096.

- ❖ Star formation in distant galaxies by the James Webb Space Telescope

Date: February 6, 2023
Source: Stockholm University



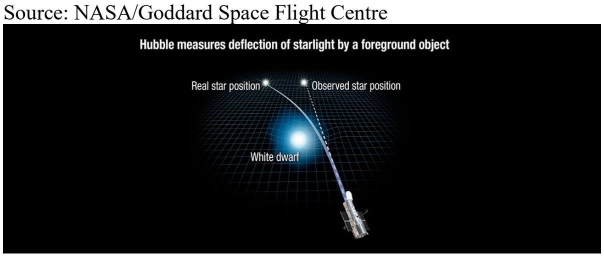
The Mid-Infrared Instrument (MIRI) on NASA’s James Webb Space Telescope took this image of NGC 1433, a barred spiral galaxy with a particularly bright core surrounded by double star-forming rings. The observations reveal cavernous bubbles of gas where forming stars have released energy.

Credit: NASA, ESA, CSA, and J. Lee (NOIRLab). Image processing: A. Pagan (STScI)

Thanks to the James Webb Space Telescope's first images of galaxy clusters, researchers have, for the very first time, been able to examine very compact structures of star clusters inside galaxies, so-called clumps. In a paper published in the *Monthly Notices of the Royal Astronomical Society,* researchers from Stockholm University have studied the first phase of star formation in distant galaxies.
"The galaxy clusters we examined are so massive that they bend light rays passing through their centre, as predicted by Einstein in 1915. And this in turn produces a kind of magnifying glass effect: the images of background galaxies are magnified," explains Adélaïde Claeyssens, Department of Astronomy, Stockholm University, one of the lead authors of the study.
The magnifying glass effect together with the resolution of the James Webb Space Telescope made it possible for the researchers to detect stellar clumps, very compact galaxy structures. These observations allowed the researchers to study the link between clump formation and evolution and galaxy growth a few million years after the Big Bang. And that in a way that has not been possible before.
"The images from the James Webb Space Telescope show that we can now detect very small structures inside very distant galaxies and that we can see these clumps in many of these galaxies. The telescope is a game-changer for the entire field of research and helps us understand how galaxies form and evolve," says Angela Adamo, Oscar Klein Centre, Stockholm University, one of the lead authors of the study.
The oldest galaxy studied in the paper is so far away that we see what it looked like 13 billion years ago, when the Universe was only 680 million years old.

- ❖ Hubble directly measures mass of a lone white dwarf

Date: February 2, 2023
Source: NASA/Goddard Space Flight Centre



Astronomers using NASA's Hubble Space Telescope have for the first time directly measured the mass of a single, isolated white dwarf -- the surviving core of a burned-out, Sun-like star.
Researchers found that the white dwarf is 56 percent the mass of our Sun. This agrees with earlier theoretical predictions of the white dwarf's mass and corroborates current theories of how white dwarfs evolve as the end product of a typical star's evolution. The unique observation yields insights into theories of the structure and composition of white dwarfs.
Until now, previous white dwarf mass measurements have been gleaned from observing white dwarfs in binary star systems. By watching the motion of two co-orbiting stars, straightforward Newtonian physics can be used to measure their masses. However, these measurements can be uncertain if the white dwarf's companion star is in a long-period orbit of hundreds or thousands of

years. Orbital motion can be measured by telescopes only over a brief slice of the dwarf's orbital motion.

For this companion-less white dwarf, researchers had to employ a trick of nature, called gravitational microlensing. The light from a background star was slightly deflected by the gravitational warping of space by the foreground dwarf star. As the white dwarf passed in front of the background star, microlensing caused the star to appear temporarily offset from its actual position on the sky.

The results are reported in the *Monthly Notices of the Royal Astronomical Society*. The lead author is Peter McGill, formerly of the University of Cambridge (now based at the University of California, Santa Cruz). McGill used Hubble to precisely measure how light from a distant star bent around the white dwarf, known as LAWD 37, causing the background star to temporarily change its apparent position in the sky.

Kailash Sahu of the Space Telescope Science Institute in Baltimore, Maryland, the principal Hubble investigator on this latest observation, first used microlensing in 2017 to measure the mass of another white dwarf, Stein 2051 B. But that dwarf is in a widely separated binary system. "Our latest observation provides a new benchmark because LAWD 37 is all by itself," Sahu said.

The collapsed remains of a star that burned out 1 billion years ago, LAWD 37 has been extensively studied because it is only 15 light-years away in the constellation Musca.

"Because this white dwarf is relatively close to us, we've got lots of data on it -- we've got information about its spectrum of light, but the missing piece of the puzzle has been a measurement of its mass," said McGill.

The team zeroed in on the white dwarf thanks to ESA's Gaia space observatory, which makes extraordinarily precise measurements of nearly 2-billion-star positions. Multiple Gaia observations can be used to track a star's motion. Based on this data, astronomers were able to predict that LAWD 37 would briefly pass in front of a background star in November 2019.

Once this was known, Hubble was used to precisely measure over several years how the background star's apparent position in the sky was temporarily deflected during the white dwarf's passage.

"These events are rare, and the effects are tiny," said McGill. "For instance, the size of our measured offset is like measuring the length of a car on the Moon as seen from Earth."

Since the light from the background star was so faint, the main challenge for astronomers was extracting its image from the glare of the white dwarf, which is 400 times brighter than the background star. Only Hubble can make these kinds of high-contrast observations in visible light.

"The precision of LAWD 37's mass measurement allows us to test the mass-radius relationship for white dwarfs," said McGill. "This means testing the theory of degenerate matter (a gas so super-compressed under gravity it behaves more like solid matter) under the extreme conditions inside this dead star," he added.

The researchers say their results open the door for future event predictions with Gaia data. In addition to Hubble, these alignments can now be detected with NASA's James Webb Space Telescope. Because Webb works at infrared wavelengths, the blue glow of a foreground white dwarf looks dimmer in infrared light, and the background star looks brighter.

Based on Gaia's predictive powers, Sahu is observing another white dwarf, LAWD 66, with NASA's James Webb Space Telescope. The first observation was done in 2022. More observations will be taken as the deflection peaks in 2024 and then subsides.

"Gaia has really changed the game -- it's exciting to be able to use Gaia data to predict when events will happen, and then observe them happening," said McGill. "We want to continue measuring the gravitational microlensing effect and obtain mass measurements for many more types of stars."

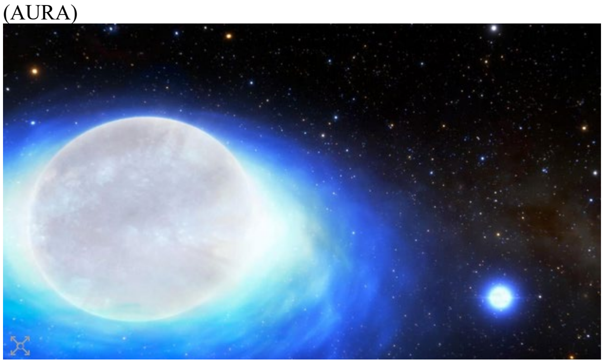
In his 1915 theory of general relativity, Einstein predicted that when a massive compact object passes in front of a background star, the light from the star would bend around the foreground object due to the warping of space by its gravitational field.

Exactly a century before this latest Hubble observation, in 1919, two British-organized expeditions to the southern hemisphere first detected this lensing effect during a solar eclipse on May 19th. It was hailed as the first experimental proof of general relativity -- that gravity warps space. However, Einstein was pessimistic that the effect could ever be detected for stars outside our solar system

because of the precision involved. "Our measurement is 625 times smaller than the effect measured at the 1919 solar eclipse," said McGill.
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 conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy, in Washington, D.C.

- Astronomers uncover a one-in-ten-billion binary star system: Kilonova progenitor system

Date: February 1, 2023
Source: Association of Universities for Research in Astronomy (AURA)



Waiting to explode Artist's impression of the kilonova progenitor showing the Be star (left) and its companion neutron star right. (Courtesy: CTIO/NOIRLab/NSF/AURA/J da Silva/Spaceengine/M Zamani)

Astronomers using the SMARTS 1.5-meter Telescope at Cerro Tololo Inter-American Observatory in Chile, a Program of NSF's NOIRLab, have uncovered the first example of a phenomenally rare type of binary star system, one that has all the right conditions to eventually trigger a kilonova -- the ultra-powerful, gold-producing explosion created by colliding neutron stars. Such an arrangement is so vanishingly rare that only about 10 such systems are thought to exist in the entire Milky Way Galaxy. The findings are published today in the journal *Nature*.
This unusual system, known as CPD-29 2176, is located about 11,400 light-years from Earth. It was first identified by NASA's Neil Gehrels Swift Observatory. Later observations with the SMARTS 1.5-meter Telescope allowed astronomers to deduce the orbital characteristics and types of stars that make up this system -- a neutron star created by an ultra-stripped supernova and a closely orbiting massive star that is in the process of becoming an ultra-stripped supernova itself.

An ultra-stripped supernova is the end-of-life explosion of a massive star that has had much of its outer atmosphere stripped away by a companion star. This class of supernova lacks the explosive force of a traditional supernova, which would otherwise "kick" a nearby companion star out of the system.
"The current neutron star would have to form without ejecting its companion from the system. An ultra-stripped supernova is the best explanation for why these companion stars are in such a tight orbit," said Noel D. Richardson at Embry-Riddle Aeronautical University and lead author of the paper. "To one day create a kilonova, the other star would also need to explode as an ultra-stripped supernova so the two neutron stars could eventually collide and merge."
As well as representing the discovery of an incredibly rare cosmic oddity, finding and studying kilonova progenitor systems such as this can help astronomers unravel the mystery of how kilonovae form, shedding light on the origin of the heaviest elements in the Universe.
"For quite some time, astronomers speculated about the exact conditions that could eventually lead to a kilonova," said NOIRLab astronomer and co-author André-Nicolas Chené. "These new results demonstrate that, in at least some cases, two sibling neutron stars can merge when one of them was created without a classical supernova explosion."
Producing such an unusual system, however, is a long and unlikely process. "We know that the Milky Way contains at least 100 billion stars and likely hundreds of billions more. This remarkable binary system is essentially a one-in-ten-billion system," said Chené. "Prior to our study, the estimate was that only one or two such systems should exist in a spiral galaxy like the Milky Way."
Though this system has all the right stuff to eventually form a kilonova, it will be up to future astronomers to study that event. It will take at least one million years for the massive star to end its life as a titanic supernova explosion and leave behind a second neutron star. This new stellar remnant and the pre-existing neutron star will then need to gradually draw together in a cosmic ballet, slowly losing their orbital energy as gravitational radiation.
When they eventually merge, the resulting kilonova explosion will produce much more powerful gravitational waves and leave

behind in its wake a large number of heavy elements, including silver and gold.
"This system reveals that some neutron stars are formed with only a small supernova kick," concluded Richardson. "As we understand the growing population of systems like CPD-29 2176 we will gain insight into how calm some stellar deaths may be and if these stars can die without traditional supernovae."

- Scientists release newly accurate map of all the matter in the universe

Analysis combines Dark Energy Survey, South Pole Telescope data to understand evolution of universe
Date: January 31, 2023
Source: University of Chicago

A team of scientists, comprising experts from the University of Chicago and Fermi National Accelerator Laboratory, have made a game-changing announcement with their release of one of the most accurate measurements to date of the universe's matter distribution.

Sometimes to know what the matter is, you have to find it first.
When the universe began, matter was flung outward and gradually formed the planets, stars and galaxies that we know and love today. By carefully assembling a map of that matter today, scientists can try to understand the forces that shaped the evolution of the universe.
A group of scientists, including several with the University of Chicago and Fermi National Accelerator Laboratory, have released one of the most precise measurements ever made of how matter is distributed across the universe today.
Combining data from two major telescope surveys of the universe, the Dark Energy Survey and the South Pole Telescope, the analysis involved more than 150 researchers and is published as a set of three articles Jan. 31 in *Physical Review D.*
Among other findings, the analysis indicates that matter is not as "clumpy" as we would expect based on our current best model of the universe, which adds to a body of evidence that there may be something missing from our existing standard model of the universe.

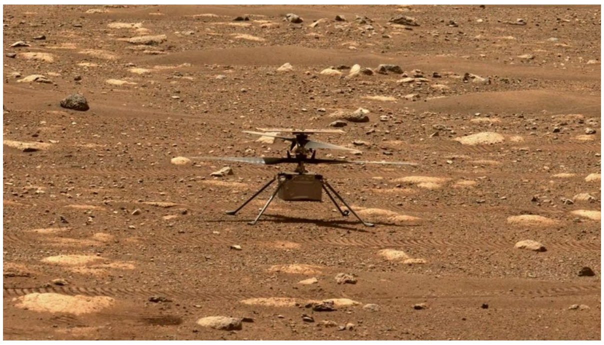
Cooling and clumps

After the Big Bang created all the matter in the universe in a very hot, intense few moments about 13 billion years ago, this matter has been spreading outward, cooling and clumping as it goes. Scientists are very interested in tracing the path of this matter; by seeing where all the matter ended up, they can try to recreate what happened and what forces would have had to have been in play.
The first step is collecting enormous amounts of data with telescopes.
In this study, scientists combined data from two very different telescope surveys: The Dark Energy Survey, which surveyed the sky over six years from a mountaintop in Chile, and the South Pole Telescope, which looks for the faint traces of radiation that are still traveling across the sky from the first few moments of the universe.
Combining two different methods of looking at the sky reduces the chance that the results are thrown off by an error in one of the forms of measurement. "It functions like a cross-check, so it becomes a much more robust measurement than if you just used one or the other," said UChicago astrophysicist Chihway Chang, one of the lead authors of the studies.
In both cases, the analysis looked at a phenomenon called *gravitational lensing.* As light travels across the universe, it can be slightly bent as it passes objects with lots of gravity, like galaxies.
This method catches both regular matter and dark matter -- the mysterious form of matter that we have only detected due to its effects on regular matter -- because both regular and dark matter exert gravity.
By rigorously analysing these two sets of data, the scientists could infer where all the matter ended up in the universe. It is more precise than previous measurements -- that is, it narrows down the possibilities for where this matter wound up -- compared to previous analyses, the authors said.
The majority of the results fit perfectly with the currently accepted best theory of the universe.
But there are also signs of a crack -- one that has been suggested in the past by other analyses, too.
"It seems like there are slightly less fluctuations in the current universe, than we would predict assuming our standard

cosmological model anchored to the early universe," said analysis co-author and University of Hawaii astrophysicist Eric Baxter (UChicago PhD'14).
That is, if you make a model incorporating all the currently accepted physical laws, then take the readings from the beginning of the universe and extrapolate it forward through time, the results look slightly different from what we actually measure around us today. Specifically, today's readings find the universe is less "clumpy" -- clustering in certain areas rather than evenly spread out -- than the model would predict.
If other studies continue to find the same results, scientists say, it may mean there is something missing from our existing model of the universe, but the results are not yet to the statistical level that scientists consider to be ironclad. That will take further study.
However, the analysis is a landmark as it yielded useful information from two very different telescope surveys. This is a much-anticipated strategy for the future of astrophysics, as more large telescopes come online in the next decades, but few had actually been carried out yet.
"I think this exercise showed both the challenges and benefits of doing these kinds of analyses," Chang said. "There's a lot of new things you can do when you combine these different angles of looking at the universe."
University of Chicago Kavli Associate Fellow Yuuki Omori was also a lead co-author for the papers. The South Pole Telescope is primarily funded by the National Science Foundation and the Department of Energy and is operated by a collaboration led by the University of Chicago. The Dark Energy Survey was an international collaboration coordinated through Fermi National Accelerator Laboratory and funded by the Department of Energy, the National Science Foundation, and many institutions around the world.

- Researchers complete first real-world study of Martian helicopter dust dynamics

Date: January 31, 2023
Source: Stevens Institute of Technology



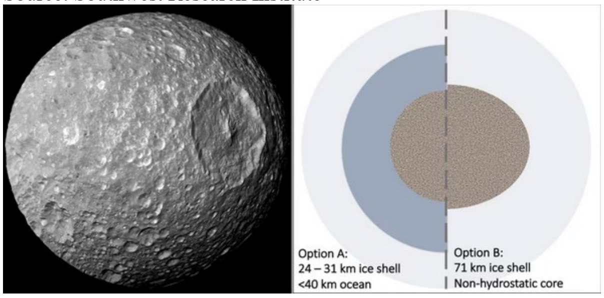
Mars is a dusty planet. From tiny dust devils to vast storms that shroud the planet, dust is a constant challenge for research missions. That was especially true for Ingenuity, the rotorcraft that since February 2021 has been exploring Mars alongside NASA's Perseverance rover. Now, researchers at Stevens Institute of Technology, the Space Science Institute, and the Jet Propulsion Laboratory have completed the first real-world study of Martian dust dynamics based on Ingenuity's historic first flights on the Red Planet, paving the way for future extra-terrestrial rotorcraft missions.
The work, reported in the December 2022 issue of *Journal of Geophysical Research: Planets*, could support NASA's Mars Sample Return Program, which will retrieve samples collected by Perseverance, or the Dragonfly mission that will set course for Titan, Saturn's largest moon, in 2027.
"There's a reason that helicopter pilots on Earth prefer to land on helipads," said Jason Rabinovitch, a co-author and assistant professor at Stevens. "When a helicopter lands in the desert, its downdraft can stir up enough dust to cause a zero-visibility 'brownout' -- and Mars is effectively one big desert."
Rabinovitch has been working on the Ingenuity program since 2014, joining the Jet Propulsion Laboratory soon after the concept was first pitched to NASA and creating the first theoretical models of helicopter dust lifting in the dusty Martian environments. At Stevens, Rabinovitch continues to work with JPL and investigates plume-surface interactions during powered descent of a spacecraft. He also models supersonic parachute inflation and geophysical phenomena, such as plumes on Enceladus.
Studying dust dynamics on another planet isn't easy, explained Rabinovitch. "Space is a data-poor environment. It's hard to send videos and images back to Earth, so we have to work with what we can get."
To overcome that challenge, Rabinovitch and colleagues at JPL used advanced image-

processing techniques to extract information from six helicopter flights, all low-resolution videos captured by Perseverance. By identifying tiny variations between video frames, and the light intensity of individual pixels, the researchers were able to calculate both the size and the total mass of dust clouds kicked up as Ingenuity took off, hovered, maneuverer, and landed.
The results were within striking distance of Rabinovitch's engineering models -- itself a remarkable achievement, given the limited information available to the team way back in 2014, when Rabinovitch and his colleagues were writing back-of-the-envelope calculations intended to support the original design of Ingenuity.
The research shows that, as predicted, dust is a significant consideration for extra-terrestrial rotorcraft, with Ingenuity estimated to have kicked up about a thousandth of its own mass (four pounds) in dust each time it flew. That's many times more dust than would be generated by an equivalent helicopter on Earth, though Rabinovitch cautions that it's tricky to draw direct comparisons.
"It was exciting to see the Mastcam-Z video from Perseverance, which was taken for engineering reasons, ended up showing Ingenuity lifting so much dust from the surface that it opened a new line of research," said Mark Lemmon, senior research scientist at the Space Science Institute Mars Science Laboratory and first author of the study.
"When you think about dust on Mars, you have to consider not just the lower gravity, but also the effects of air pressure, temperature, air density -- there's a lot we don't yet fully understand," Rabinovitch said. Still, he added, that's what makes studying Ingenuity's dust clouds so exciting.
A better understanding of brownouts could help NASA extend future robotic missions by keeping solar panels operational for longer or make it easier to land delicate equipment safely on the dusty Martian surface. It could also offer new insights into the role of wind and wind-carried dust in weather patterns and erosion, both on Earth and in extreme environments around the Solar System.
Video: https://youtu.be/MqD5-2buHZE

- Evidence that Saturn's moon Mimas is a stealth ocean world

Simulations suggest that Saturn's smallest, innermost moon could have an expanding, geologically young ocean

Date: January 31, 2023
Source: Southwest Research Institute



Researchers modelled the Herschel impact basin on Mimas, suggesting that the Saturn moon may have a thinning ice shell surrounding a geologically young internal ocean. (Image credit: NASA/JPL/SSI/SwRI)

When a Southwest Research Institute scientist discovered surprising evidence that Saturn's smallest, innermost moon could generate the right amount of heat to support a liquid internal ocean, colleagues began studying Mimas' surface to understand how its interior may have evolved. Numerical simulations of the moon's Herschel impact basin, the most striking feature on its heavily cratered surface, determined that the basin's structure and the lack of tectonics on Mimas are compatible with a thinning ice shell and geologically young ocean.
"In the waning days of NASA's Cassini mission to Saturn, the spacecraft identified a curious libration, or oscillation, in Mimas' rotation, which often points to a geologically active body able to support an internal ocean," said SwRI's Dr. Alyssa Rhoden, a specialist in the geophysics of icy satellites, particularly those containing oceans, and the evolution of giant planet satellite systems. She is the second author of a new *Geophysical Research Letters* paper on the subject. "Mimas seemed like an unlikely candidate, with its icy, heavily cratered surface marked by one giant impact crater that makes the small moon look much like the Death Star from *Star Wars*. If Mimas has an ocean, it represents a new class of small, 'stealth' ocean worlds with surfaces that do not betray the ocean's existence."
Rhoden worked with Purdue graduate student Adeene Denton to better understand how a heavily cratered moon like Mimas could possess an internal ocean. Denton modelled the formation of the Hershel impact basin using iSALE-2D simulation software. The models showed that Mimas' ice shell had to be at least 34 miles (55 km) thick at the time of

the Herschel-forming impact. In contrast, observations of Mimas and models of its internal heating limit the present-day ice shell thickness to less than 19 miles (30 km) thick, if it currently harbours an ocean. These results imply that a present-day ocean within Mimas must have been warming and expanding since the basin formed. It is also possible that Mimas was entirely frozen both at the time of the Herschel impact and at present. However, Denton found that including an interior ocean in impact models helped produce the shape of the basin.

"We found that Herschel could not have formed in an ice shell at the present-day thickness without obliterating the ice shell at the impact site," said Denton, who is now a post-doctoral researcher at the University of Arizona. "If Mimas has an ocean today, the ice shell has been thinning since the formation of Herschel, which could also explain the lack of fractures on Mimas. If Mimas is an emerging ocean world, that places important constraints on the formation, evolution and habitability of all of the mid-sized moons of Saturn."

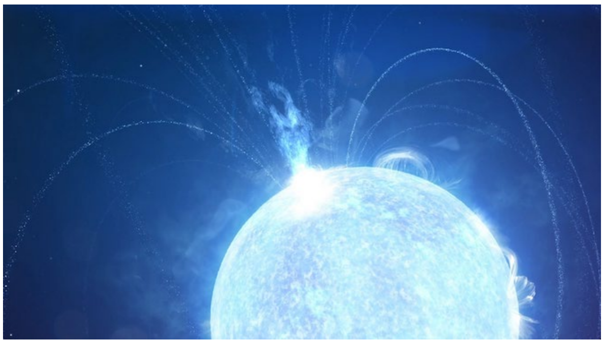
"Although our results support a present-day ocean within Mimas, it is challenging to reconcile the moon's orbital and geologic characteristics with our current understanding of its thermal-orbital evolution," Rhoden said. "Evaluating Mimas' status as an ocean moon would benchmark models of its formation and evolution. This would help us better understand Saturn's rings and mid-sized moons as well as the prevalence of potentially habitable ocean moons, particularly at Uranus. Mimas is a compelling target for continued investigation."

Rhoden is co-leader of NASA's Network for Ocean Worlds Research Coordination Network and previously served on the National Academies' Committee on Astrobiology and Planetary Science.

- Volcano-like rupture could have caused magnetar slowdown

Star's sudden 2020 slowdown allows for test of 'anti-glitch' theory

Date: January 27, 2023
Source: Rice University



View larger. | Artist's concept a magnetar, or strongly magnetic star, with an eruption on its surface. The eruption must be exceedingly powerful, because magnetars are neutron stars. And neutron stars have immensely strong gravity, billions of times stronger than on Earth. Still, a new study suggests that magnetar eruptions are responsible for sudden slowdowns in a magnetar's rate of spin. Astronomers believe they saw this happen in 2020. Image via NASA's Goddard Space Flight Centre/ Chris Smith (USRA).

On Oct. 5, 2020, the rapidly rotating corpse of a long-dead star about 30,000 light years from Earth changed speeds. In a cosmic instant, its spinning slowed. And a few days later, it abruptly started emitting radio waves.

Thanks to timely measurements from specialized orbiting telescopes, Rice University astrophysicist Matthew Baring and colleagues were able to test a new theory about a possible cause for the rare slowdown, or "anti-glitch," of SGR 1935+2154, a highly magnetic type of neutron star known as a magnetar.

In a study published this month in *Nature Astronomy*, Baring and co-authors used X-ray data from the European Space Agency's X-ray Multi-Mirror Mission (XMM-Newton) and NASA's Neutron Star Interior Composition Explorer (NICER) to analyse the magnetar's rotation. They showed the sudden slowdown could have been caused by a volcano-like rupture on the surface of the star that spewed a "wind" of massive particles into space. The research identified how such a wind could alter the star's magnetic fields, seeding conditions that would be likely to switch on the radio emissions that were subsequently measured by China's Five-hundred-meter Aperture Spherical Telescope (FAST).

"People have speculated that neutron stars could have the equivalent of volcanoes on their surface," said Baring, a professor of physics and astronomy. "Our findings suggest that could be the case and that on this occasion, the rupture was most likely at or near the star's magnetic pole."

SGR 1935+2154 and other magnetars are a type of neutron star, the compact remains of a dead star that collapsed under intense gravity. About a dozen miles wide and as dense as the nucleus of an atom, magnetars rotate once every few seconds and feature the most intense magnetic fields in the universe.

Magnetars emit intense radiation, including X-rays and occasional radio waves and gamma rays. Astronomers can decipher much about the unusual stars from those emissions. By counting pulses of X-rays, for example, physicists can calculate a magnetar's rotational period, or the amount of time it takes to make one complete rotation, as the Earth does in one day. The rotational periods of magnetars typically change slowly, taking tens of thousands of years to slow by a single rotation per second.

Glitches are abrupt increases in rotational speed that are most often caused by sudden shifts deep within the star, Baring said.

"In most glitches, the pulsation period gets shorter, meaning the star spins a bit faster than it had been," he said. "The textbook explanation is that over time, the outer, magnetized layers of the star slow down, but the inner, non-magnetized core does not. This leads to a build-up of stress at the boundary between these two regions, and a glitch signals a sudden transfer of rotational energy from the faster spinning core to the slower spinning crust."

Abrupt rotational slowdowns of magnetars are very rare. Astronomers have only recorded three of the "anti-glitches," including the October 2020 event.

While glitches can be routinely explained by changes inside the star, anti-glitches likely cannot. Baring's theory is based on the assumption that they are caused by changes on the surface of the star and in the space around it. In the new paper, he and his co-authors constructed a volcano-driven wind model to explain the measured results from the October 2020 anti-glitch.

Baring said the model uses only standard physics, specifically changes in angular momentum and conservation of energy, to account for the rotational slowdown.

"A strong, massive particle wind emanating from the star for a few hours could establish the conditions for the drop in rotational period," he said. "Our calculations showed such a wind would also have the power to change the geometry of the magnetic field outside the neutron star."

The rupture could be a volcano-like formation, because "the general properties of the X-ray pulsation likely require the wind to be launched from a localized region on the surface," he said.

"What makes the October 2020 event unique is that there was a fast radio burst from the magnetar just a few days after the anti-glitch, as well as a switch-on of pulsed, ephemeral radio emission shortly thereafter," he said.

"We've seen only a handful of transient pulsed radio magnetars, and this is the first time we've seen a radio switch-on of a magnetar almost contemporaneous with an anti-glitch."

Baring argued this timing coincidence suggests the anti-glitch and radio emissions were caused by the same event, and he's hopeful that additional studies of the volcanism model will provide more answers.

"The wind interpretation provides a path to understanding why the radio emission switches on," he said. "It provides new insight we have not had before."

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