South Downs Mercury

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Main Talk Ian Smith "Ian will give a talk following on from his talk on imaging planetary nebulae in April 2024. This time he will enlighten us about planetary nebulae as objects in their own right" I've been an amateur astronomer for several decades and used to be chairman of the Abingdon Astronomical Society for many years. My own astronomical interests started with planetary observing and then imaging. Then when the planets effectively disappeared from UK skies, I turned to imaging PNe, which I've now been doing now for the last 6 years or so.

Please support a raffle we are organizing this month.

- Black holes: not endings, but beginnings? New research could revolutionize our understanding of the universe

Date: March 12, 2025
Source: University of Sheffield

Credit: Philip Drury, University of Sheffield

New research suggests black holes may transition into 'white holes', ejecting matter and potentially even time back into the universe, defying our current understanding of these cosmic giants. The study by the University of Sheffield proposes a revolutionary link between time and dark energy, suggesting that the mysterious force driving the universe's expansion may be used to measure time.

Our understanding of black holes, time and the mysterious dark energy that dominates the universe could be revolutionised, as new University of Sheffield research helps unravel the mysteries of the cosmos.

Black holes -- areas of space where gravity is so strong that not even light can escape -- have long been objects of fascination, with astrophysicists, theoretical physicists and others dedicating their lives to revealing their secrets. This fascination with the unknown has inspired numerous writers and filmmakers, with novels and films such as 2001: A Space Odyssey, The Martian and Interstellar exploring these enigmatic objects' hold on our collective imagination.

According to Einstein's Theory of General Relativity, anyone trapped inside a black hole would fall towards its centre and be destroyed by immense gravitational forces. This centre, known as a singularity, is the point where the matter of a giant star, which is believed to have collapsed to form the black hole, is crushed down into an infinitesimally tiny point. At this singularity, our understanding of physics and time breaks down.

Using the laws of quantum mechanics, a fundamental theory describing the nature of the universe at the level of atoms and even smaller particles, the new study proposes a radically different theoretical standpoint where, rather than a singularity signifying the end, it could represent a new beginning.

The new paper entitled 'Black Hole Singularity Resolution in Unimodular Gravity from Unitarity', published today in the scientific journal *Physical Review Letters*, aims to illustrate the point where our current grasp of physics and time falters.

While black holes are often described as sucking everything, including time, into a point of nothingness, in the paper, white holes are theorised to act in reverse, ejecting matter, energy and time back into the universe.

The study uses a simplified, theoretical model of a black hole, known as a planar black hole. Unlike typical black holes, which have a spherical shape, a planar black hole's boundary is a flat, two-dimensional surface.

The researchers' ongoing work suggests that

the same mechanism could also apply to a typical black hole.
"It has long been a question as to whether quantum mechanics can change our understanding of black holes and give us insights into their true nature," said Dr Steffen Gielen, from the University of Sheffield's School of Mathematical and Physical Sciences, who co-wrote the paper with Lucía Menéndez-Pidal from Complutense University of Madrid.
"In quantum mechanics, time as we understand it cannot end as systems perpetually change and evolve."
The scientists' findings demonstrate how, using the laws of quantum mechanics, the black hole singularity is replaced by a region of large quantum fluctuations -- tiny, temporary changes in the energy of space -- where space and time do not end. Instead, space and time transition into a new phase called a white hole -- a theoretical region of space thought to function in the opposite way to a black hole. As such, a white hole could be where time begins.
"While time is, in general, thought to be relative to the observer, in our research time is derived from the mysterious dark energy which permeates the entire universe," Dr Gielen continued.
"We propose that time is measured by the dark energy that is everywhere in the Universe, and responsible for its current expansion. This is the pivotal new idea that allows us to grasp the phenomena occurring within a black hole."
Dark energy is a mysterious, theoretical force that scientists believe drives the accelerating expansion of the universe. The new study uses dark energy almost as a point of reference, with energy and time as complementary ideas that can be measured against one another.
Tantalisingly, the theory that what we perceive as a singularity is actually a beginning suggests the existence of something even more enigmatic on the other side of a white hole.
"Hypothetically you could have an observer -- a hypothetical entity -- go through the black hole, through what we think of as a singularity and emerge on the other side of the white hole. It's a highly abstract notion of an observer but it could happen, in theory," Dr Gielen added.
Beyond such theoretical musings, the suggestion of a profound connection between the nature of time at the most fundamental level and the mysterious dark energy that governs the cosmos will be explored further in the months and years ahead.
The new research also suggests novel approaches to reconciling gravity and quantum mechanics, potentially paving the way for groundbreaking new fundamental theories and breakthroughs in our understanding of the universe.

- Four tiny planets found orbiting one of our nearest stars

MAROON-X instrument finds evidence for planets around famous Barnard's Star
Date: March 11, 2025
Source: University of Chicago


An illustration depicts what the surface of one of the exoplanets orbiting Barnard's Star may look like. The other three planets within the system can also be seen.
International Gemini Observatory/NSF's NOIRLab/International Gemini Observatory

Astronomers have revealed new evidence that there are not just one but four tiny planets circling around Barnard's Star, the second-nearest star system to Earth.
The four planets, each only about 20 to 30% the mass of Earth, are so close to their home star that they zip around the entire star in a matter of days. That probably means they are too hot to be habitable, but the find is a new benchmark for discovering smaller planets around nearby stars.
"It's a really exciting find -- Barnard's Star is our cosmic neighbour, and yet we know so little about it," said Ritvik Basant, Ph.D student at the University of Chicago and first author on the study. "It's signalling a breakthrough with the precision of these new instruments from previous generations."
The finding adds weight to a November study by a team using a different telescope, which had found strong evidence for one planet around Barnard's Star and hints at others.
The new study, which included scientists with the Gemini Observatory/National Science Foundation NOIRLab, Heidelberg University, and the University of Amsterdam, is published March 11 in *The Astrophysical Journal Letters*.

Star wobbles

For a century, astronomers have been studying Barnard's Star in hopes of finding planets around it. First discovered by E. E. Barnard at Yerkes Observatory in 1916, it is the nearest system that has the same configuration we do -- i.e., with only one star. (The absolute nearest star system to us, Proxima Centauri, has three stars circling each other, which changes the dynamics of planet formation and orbits).

Barnard's Star is a type called an M dwarf star, which we now know are extremely numerous in the universe. Scientists, therefore, would like to know more about what kinds of planets they host.

The trouble is that these faraway planets are far too tiny to be seen next to the brilliance of their stars, even with our most powerful telescopes. That means scientists have had to get creative to search for them.

One such effort was led by UChicago Prof. Jacob Bean, whose team created and installed an instrument called MAROON-X, which is attached to the Gemini Telescope on a Hawaiian mountaintop and designed specifically to search for distant planets.

Because stars are so much brighter than their planets, it's easier to look for effects that planets have on their stars -- like monitoring the wind by watching how a flag moves.

MAROON-X looks for one such effect; the gravity of each planet tugs slightly on the star's position, meaning the star seems to wobble back and forth. MAROON-X measures the colour of the light so precisely that it can pick up these minor shifts, and even tease apart the number and masses of the planets that must be circling the star to have this effect.

Basant, Bean, and the team rigorously calibrated and analysed data taken during 112 different nights over a period of three years. They found solid evidence for three planets around Barnard's Star.

When the team combined their findings with data from the November experiment by a different team, which was taken by an instrument called ESPRESSO at the Very Large Telescope in Chile, they saw good evidence for a fourth planet.

These planets are likely rocky planets, rather than gas planets like Jupiter, the scientists said. That will be difficult to pin down with certainty; the angle we see them from Earth means we can't watch them cross in front of their star, which is the usual method to find out if a planet is rocky. But by gathering information about similar planets around other stars, we can make better guesses about their makeup.

However, the team was able to rule out, with a fair degree of certainty, the existence of other planets in the habitable zone around Barnard's Star.

'Really exciting'

Barnard's Star has been called the "great white whale" for planet hunters; several times over the past century, groups have announced evidence that suggested planets around Barnard's Star, only for them to be later disproved.

But these latest findings, independently confirmed in two different studies by the different instruments ESPRESSO and MAROON-X, mean a much larger degree of confidence than any previous result.

"We observed at different times of night on different days. They're in Chile; we're in Hawaii. Our teams didn't coordinate with each other at all," Basant said. "That gives us a lot of assurance that these aren't phantoms in the data."

These are among the smallest planets yet found with this observing technique. The scientists hope this will mark a new era of finding more and more planets in the universe.

Most of the rocky planets we've found so far are much larger than Earth, and they appear to be fairly similar across the galaxy. But there are reasons to think the smaller planets will have more widely varied compositions. As we find more of them, we can begin to tease out more information about how these planets form -- and what makes planets likely to have habitable conditions.

The find itself was exciting, too, the scientists said.

"We worked on this data really intensely at the end of December, and I was thinking about it all the time," Bean said. "It was like, suddenly we know something that no one else does about the universe. We just couldn't wait to get this secret out.

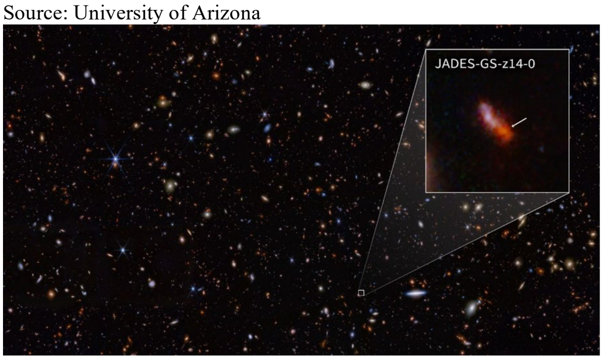
"A lot of what we do can be incremental, and it's sometimes hard to see the bigger picture," he said. "But we found something that humanity will hopefully know forever. That sense of discovery is incredible."

Additional University of Chicago authors on the paper were postdoctoral fellows Rafael Luque, Lily L. Zhao, Tanya Das, and David

Kasper; graduate student Madison Brady; postbaccalaureate student Nina Brown; and masters student Rohan Gupta

- ❖ James Webb Space Telescope reveals unexpected complex chemistry in primordial galaxy

Date: March 10, 2025
Source: University of Arizona

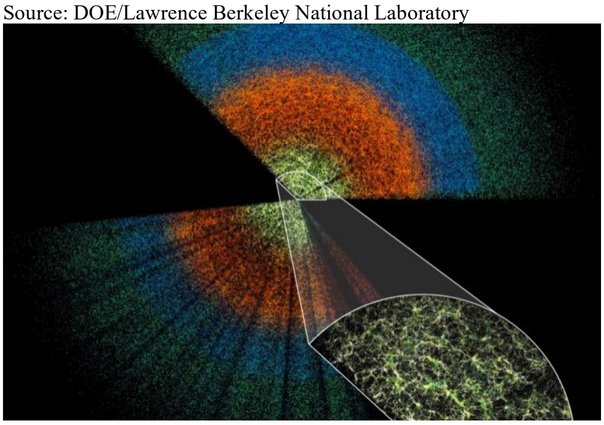


University of Arizona astronomers have learned more about a surprisingly mature galaxy that existed when the universe was just less than 300 million years old -- just 2% of its current age.
Observed by NASA's James Webb Space Telescope, the galaxy -- designated JADES-GS-z14-0 -- is unexpectedly bright and chemically complex for an object from this primordial era, the researchers said. This provides a rare glimpse into the universe's earliest chapter.
The findings, published in the journal *Nature Astronomy*, build upon the researchers' previous discovery, reported in 2024, of JADES-GS-z14-0 as the most distant galaxy ever observed. While the initial discovery established the galaxy's record-breaking distance and unexpected brightness, this new research delves deeper into its chemical composition and evolutionary state.
The work was done as part of the JWST Advanced Deep Extragalactic Survey, or JADES, a major James Webb Space Telescope program designed to study distant galaxies.
This wasn't simply stumbling upon something unexpected, said Kevin Hainline, co-author of the new study and an associate research professor at the U of A Steward Observatory. The survey was deliberately designed to find distant galaxies, but this one broke the team's records in ways they didn't anticipate -- it was intrinsically bright and had a complex chemical composition that was totally unexpected so early in the universe's history.
"It's not just a tiny little nugget. It's bright and fairly extended for the age of the universe when we observed it," Hainline said.
"The fact that we found this galaxy in a tiny region of the sky means that there should be more of these out there," said lead study author Jakob Helton, a graduate researcher at Steward Observatory. "If we looked at the whole sky, which we can't do with JWST, we would eventually find more of these extreme objects."
The research team used multiple instruments on board JWST, including the Near Infrared Camera, or NIRCam, whose construction was led by U of A Regents Professor of Astronomy Marcia Rieke. Another instrument on the telescope -- the Mid-Infrared Instrument, or MIRI, revealed something extraordinary: significant amounts of oxygen.
In astronomy, anything heavier than helium is considered a "metal," Helton said. Such metals require generations of stars to produce. The early universe contained only hydrogen, helium and trace amounts of lithium. But the discovery of substantial oxygen in the JADES-GS-z14-0 galaxy suggests the galaxy had been forming stars for potentially 100 million years before it was observed.
To make oxygen, the galaxy must have started out very early on, because it would have had to form a generation of stars, said George Rieke, Regents Professor of Astronomy and the study's senior author. Those stars must have evolved and exploded as supernovae to release oxygen into interstellar space, from which new stars would form and evolve.
"It's a very complicated cycle to get as much oxygen as this galaxy has. So, it is genuinely mind boggling," Rieke said.
The finding suggests that star formation began even earlier than scientists previously thought, which pushes back the timeline for when the first galaxies could have formed after the Big Bang.
The observation required approximately nine days of telescope time, including 167 hours of NIRCam imaging and 43 hours of MIRI imaging, focused on an incredibly small portion of the sky.
The U of A astronomers were lucky that this galaxy happened to sit in the perfect spot for them to observe with MIRI. If they had pointed the telescope just a fraction of a degree in any direction, they would have missed getting this crucial mid-infrared data, Helton said.

"Imagine a grain of sand at the end of your arm. You see how large it is on the sky -- that's how large we looked at," Helton said. The existence of such a developed galaxy so early in cosmic history serves as a powerful test case for theoretical models of galaxy formation.
"Our involvement here is a product of the U of A leading in infrared astronomy since the mid-'60s, when it first started. We had the first major infrared astronomy group over in the Lunar and Planetary lab, with Gerard Kuiper, Frank Low and Harold Johnson," Rieke said.
As humans gain the ability to directly observe and understand galaxies that existed during the universe's infancy, it can provide crucial insights into how the universe evolved from simple elements to the complex chemistry necessary for life as we know it.
"We're in an incredible time in astronomy history," Hainline said. "We're able to understand galaxies that are well beyond anything humans have ever found and see them in many different ways and really understand them. That's really magic."

- New DESI results strengthen hints that dark energy may evolve

Date: March 20, 2025
Source: DOE/Lawrence Berkeley National Laboratory



The Dark Energy Spectroscopic Instrument (DESI) released its most detailed analysis yet of dark energy, the mysterious force driving the Universe’s expansion.

The fate of the universe hinges on the balance between matter and dark energy: the fundamental ingredient that drives its accelerating expansion. New results from the Dark Energy Spectroscopic Instrument (DESI) collaboration use the largest 3D map of our universe ever made to track dark energy's influence over the past 11 billion years. Researchers see hints that dark energy, widely thought to be a "cosmological constant," might be evolving over time in unexpected ways.
DESI is an international experiment with more than 900 researchers from over 70 institutions around the world and is managed by the U.S. Department of Energy's Lawrence Berkeley National Laboratory (Berkeley Lab). The collaboration shared their findings today in multiple papers that will be posted on the online repository arXiv and in a presentation at the American Physical Society's Global Physics Summit in Anaheim, California.
"What we are seeing is deeply intriguing," said Alexie Leauthaud-Harnett, co-spokesperson for DESI and a professor at UC Santa Cruz. "It is exciting to think that we may be on the cusp of a major discovery about dark energy and the fundamental nature of our universe."
Taken alone, DESI's data are consistent with our standard model of the universe: Lambda CDM (where CDM is cold dark matter and Lambda represents the simplest case of dark energy, where it acts as a cosmological constant). However, when paired with other measurements, there are mounting indications that the impact of dark energy may be weakening over time and that other models may be a better fit. Those other measurements include the light leftover from the dawn of the universe (the cosmic microwave background or CMB), exploding stars (supernovae), and how light from distant galaxies is warped by gravity (weak lensing).
"We're guided by Occam's razor, and the simplest explanation for what we see is shifting," said Will Percival, co-spokesperson for DESI and a professor at the University of Waterloo. "It's looking more and more like we may need to modify our standard model of cosmology to make these different datasets make sense together -- and evolving dark energy seems promising."
So far, the preference for an evolving dark energy has not risen to "5 sigma," the gold standard in physics that represents the threshold for a discovery. However, different combinations of DESI data with the CMB, weak lensing, and supernovae datasets range from 2.8 to 4.2 sigma. (A 3-sigma event has a 0.3% chance of being a statistical fluke, but many 3-sigma events in physics have faded away with more data.) The analysis used a technique to hide the results from the scientists until the end, mitigating any unconscious bias about the data.
"We're in the business of letting the universe tell us how it works, and maybe the universe

is telling us it's more complicated than we thought it was," said Andrei Cuceu, a postdoctoral researcher at Berkeley Lab and co-chair of DESI's Lyman-alpha working group, which uses the distribution of intergalactic hydrogen gas to map the distant universe. "It's interesting and gives us more confidence to see that many different lines of evidence are pointing in the same direction."

DESI is one of the most extensive surveys of the cosmos ever conducted. The state-of-the-art instrument, which capture light from 5,000 galaxies simultaneously, was constructed and is operated with funding from the DOE Office of Science. DESI is mounted on the U.S. National Science Foundation's Nicholas U. Mayall 4-meter Telescope at Kitt Peak National Observatory (a program of NSF NOIRLab) in Arizona. The experiment is now in its fourth of five years surveying the sky, with plans to measure roughly 50 million galaxies and quasars (extremely distant yet bright objects with black holes at their cores) by the time the project ends.

The new analysis uses data from the first three years of observations and includes nearly 15 million of the best measured galaxies and quasars. It's a major leap forward, improving the experiment's precision with a dataset that is more than double what was used in DESI's first analysis, which also hinted at an evolving dark energy.

"It's not just that the data continue to show a preference for evolving dark energy, but that the evidence is stronger now than it was," said Seshadri Nadathur, professor at the University of Portsmouth and co-chair of DESI's Galaxy and Quasar Clustering working group. "We've also performed many additional tests compared to the first year, and they're making us confident that the results aren't driven by some unknown effect in the data that we haven't accounted for."

DESI tracks dark energy's influence by studying how matter is spread across the universe. Events in the very early universe left subtle patterns in how matter is distributed, a feature called baryon acoustic oscillations (BAO). That BAO pattern acts as a standard ruler, with its size at different times directly affected by how the universe was expanding. Measuring the ruler at different distances shows researchers the strength of dark energy throughout history. DESI's precision with this approach is the best in the world.

"For a couple of decades, we've had this standard model of cosmology that is really impressive," said Willem Elbers, a postdoctoral researcher at Durham University and co-chair of DESI's Cosmological Parameter Estimation working group, which works out the numbers that describe our universe. "As our data are getting more and more precise, we're finding potential cracks in the model and realizing we may need something new to explain all the results together."

The collaboration will soon begin work on additional analyses to extract even more information from the current dataset, and DESI will continue collecting data. Other experiments coming online over the next several years will also provide complementary datasets for future analyses.

"Our results are fertile ground for our theory colleagues as they look at new and existing models, and we're excited to see what they come up with," said Michael Levi, DESI director and a scientist at Berkeley Lab. "Whatever the nature of dark energy is, it will shape the future of our universe. It's pretty remarkable that we can look up at the sky with our telescopes and try to answer one of the biggest questions that humanity has ever asked."

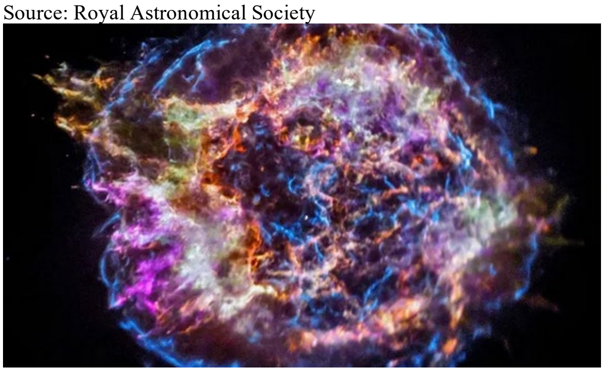
Videos discussing the experiment's new analysis are available on the DESI YouTube channel. Alongside unveiling its latest dark energy results at the APS meeting today, the DESI collaboration also announced that its Data Release 1 (DR1), which contains the first 13 months of main survey data, is now available for anyone to explore. With information on millions of celestial objects, the dataset will support a wide range of astrophysical research by others, in addition to DESI's cosmology goals.

DESI is supported by the DOE Office of Science and by the National Energy Research Scientific Computing Centre, a DOE Office of Science national user facility. Additional support for DESI is provided by the U.S. National Science Foundation; the Science and Technology Facilities Council of the United Kingdom; the Gordon and Betty Moore Foundation; the Heising-Simons Foundation; the French Alternative Energies and Atomic Energy Commission (CEA); the National Council of Humanities, Sciences, and Technologies of Mexico; the Ministry of

Science and Innovation of Spain; and by the DESI member institutions.
The DESI collaboration is honoured to be permitted to conduct scientific research on I'oligam Du'ag (Kitt Peak), a mountain with particular significance to the Tohono O'odham Nation.

- Violent supernovae 'triggered at least two Earth extinctions'

Date: March 13, 2025
Source: Royal Astronomical Society



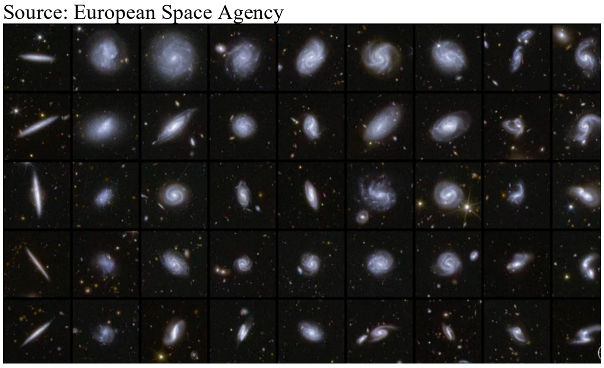
An image of Cassiopeia A (Cas A), the remnant of a massive star that exploded about 300 years ago. A new study suggests deaths of nearby massive stars may have played a significant role in triggering at least two mass extinction events in Earth's history. (Image credit: NASA/CXC/SAO)

At least two mass extinction events in Earth's history were likely caused by the "devastating" effects of nearby supernova explosions, a new study suggests.
Researchers at Keele University say these super-powerful blasts -- caused by the death of a massive star -- may have previously stripped our planet's atmosphere of its ozone, sparked acid rain and exposed life to harmful ultraviolet radiation from the Sun.
They believe a supernova explosion close to Earth could be to blame for both the late Devonian and Ordovician extinction events, which occurred 372 and 445 million years ago respectively.
The Ordovician extinction killed 60 per cent of marine invertebrates at a time when life was largely confined to the sea, while the late Devonian wiped out around 70 per cent of all species and led to huge changes in the kind of fish that existed in our ancient seas and lakes.
Past research has failed to identify a clear cause for either event, although they are thought to have been linked to the depletion of Earth's ozone layer, which could have been triggered by a supernova.
The new study, published today in *Monthly Notices of the Royal Astronomical Society*, found that the rate supernovae occur near to our planet is consistent with the timings of both mass extinctions.
The authors say it is a "a great illustration for how massive stars can act as both creators and destructors of life."
That's because supernovae are also known to spread the heavy elements that help form and support life across the universe.
Supernovae occur when massive stars reach the end of their lives, run out of fuel, cool off, and then collapse under the pressure of gravity. The explosions are the biggest humans have ever seen.
Lead author Dr Alexis Quintana, formerly from Keele University and now at the University of Alicante, said: "Supernova explosions bring heavy chemical elements into the interstellar medium, which are then used to form new stars and planets.
"But if a planet, including the Earth, is located too close to this kind of event, this can have devastating effects."
Dr Nick Wright, from Keele University, added: "Supernova explosions are some of the most energetic explosions in the universe.
"If a massive star were to explode as a supernova close to the Earth, the results would be devastating for life on Earth. This research suggests that this may have already happened."
The researchers came to their conclusion after carrying out a "census" of massive stars within a kiloparsec (around 3,260 light-years) of the Sun.
They were studying the distribution of these massive stars, known as OB stars, to learn more about how star clusters and galaxies form by using the Milky Way itself as a benchmark, and the rate at which these stars form in our galaxy.
This census allowed the researchers to calculate the rate at which supernovae occur within the galaxy, which is important for observations of supernovae, and the production of supernova remnants and massive stellar remnants such as black holes and neutron stars throughout the universe.
The data will also be useful for future development of gravitational wave detectors, which are a useful tool for scientists studying the structure and origins of the universe.
As part of this the research team calculated the supernova rate within 20 parsecs of the Sun, or approximately 65 light-years, and compared this with the approximate rate of mass extinction events on Earth that have previously been attributed to nearby supernovae.

This excludes extinction events linked to other factors such as asteroid impacts or the ice ages.
Comparing these data sets, the experts found that their research supported the theory that a supernova explosion was responsible for both the late Devonian and Ordovician extinction events -- two of the five known mass extinctions in Earth's history.
"We calculated the supernova rate close to Earth and found it to be consistent with the rate of mass extinction events on our planet that have been linked to external forces such as supernovae," Dr Wright explained.
Astronomers believe about one or two supernovae -- or possibly at a rate even lower than that -- occur each century in galaxies like the Milky Way, but the good news is there are only two nearby stars which could go supernova within the next million years or so: Antares and Betelgeuse.
However, both of these are more than 500 light-years away from us and computer simulations have previously suggested a supernova at that distance from Earth likely wouldn't affect our planet.

- Treasure trove of galaxies, glimpses of deep fields

Date: March 19, 2025
Source: European Space Agency



This image shows examples of galaxies in different shapes, all captured by Euclid during its first observations of the… [more]
© ESA/Euclid/Euclid Consortium/NASA, image processing by M. Walmsley, M. Huertas-Company, J.-C. Cuillandre

On 19 March 2025, the European Space Agency's Euclid mission releases its first batch of survey data, including a preview of its deep fields. Here, hundreds of thousands of galaxies in different shapes and sizes take centre stage and show a glimpse of their large-scale organisation in the cosmic web.
Covering a huge area of the sky in three mosaics, the data release also includes numerous galaxy clusters, active galactic nuclei and transient phenomena, as well as the first classification survey of more than 380,000 galaxies and 500 gravitational lens candidates compiled through combined artificial intelligence and citizen science efforts. All of this sets the scene for the broad range of topics that the dark Universe detective Euclid is set to address with its rich dataset.
"Euclid shows itself once again to be the ultimate discovery machine. It is surveying galaxies on the grandest scale, enabling us to explore our cosmic history and the invisible forces shaping our Universe," says ESA's Director of Science, Prof. Carole Mundell. "With the release of the first data from Euclid's survey, we are unlocking a treasure trove of information for scientists to dive into and tackle some of the most intriguing questions in modern science. With this, ESA is delivering on its commitment to enable scientific progress for generations to come."

Tracing out the cosmic web in Euclid's deep fields

Euclid has scouted out the three areas in the sky where it will eventually provide the deepest observations of its mission. In just one week of observations, with one scan of each region so far, Euclid already spotted 26 million galaxies. The farthest of those are up to 10.5 billion light-years away. The fields also contain a small population of bright quasars that can be seen much farther away.
In the coming years, Euclid will pass over these three regions tens of times, capturing many more faraway galaxies, making these fields truly 'deep' by the end of the nominal mission in 2030.
But the first glimpse of 63 square degrees of the sky, the equivalent area of more than 300 times the full Moon, already gives an impressive preview of the scale of Euclid's grand cosmic atlas when the mission is complete. This atlas will cover one-third of the entire sky -- 14,000 square degrees -- in this high-quality detail.
"It's impressive how one observation of the deep field areas has already given us a wealth of data that can be used for a variety of purposes in astronomy: from galaxy shapes, to strong lenses, clusters, and star formation, among others," says Valeria Pettorino, ESA's Euclid project scientist. "We will observe each deep field between 30 and 52 times over Euclid's six-year mission, each time improving the resolution of how we see those areas, and the number of objects we manage to observe. Just think of the discoveries that await us."

To answer the mysteries it is designed for, Euclid measures the huge variety of shapes and the distribution of billions of galaxies very precisely with its high-resolution imaging visible instrument (VIS), while its near-infrared instrument (NISP) is essential for unravelling galaxy distances and masses. The new images already showcase this capability for hundreds of thousands of galaxies, and start to hint at the large-scale organisation of these galaxies in the cosmic web. These filaments of ordinary matter and dark matter weave through the cosmos, and from these, galaxies formed and evolved. This is an essential piece in the puzzle towards understanding the mysterious nature of dark matter and dark energy, which together appear to make up 95% of the Universe.

"The full potential of Euclid to learn more about dark matter and dark energy from the large-scale structure of the cosmic web will be reached only when it has completed its entire survey. Yet the volume of this first data release already offers us a unique first glance at the large-scale organisation of galaxies, which we can use to learn more about galaxy formation over time," says Clotilde Laigle, Euclid Consortium scientist and data processing expert based at the Institut d'Astrophysique de Paris, France.

Humans and AI classify more than 380,000 galaxies

Euclid is expected to capture images of more than 1.5 billion galaxies over six years, sending back around 100 GB of data every day. Such an impressively large dataset creates incredible discovery opportunities, but huge challenges when it comes to searching for, analysing and cataloguing galaxies. The advancement of artificial intelligence (AI) algorithms, in combination with thousands of human citizen science volunteers and experts, is playing a critical role.

"We're at a pivotal moment in terms of how we tackle large-scale surveys in astronomy. AI is a fundamental and necessary part of our process in order to fully exploit Euclid's vast dataset," says Mike Walmsley, Euclid Consortium scientist based at the University of Toronto, Canada, who has been heavily involved in astronomical deep learning algorithms for the last decade.

"We're building the tools as well as providing the measurements. In this way we can deliver cutting-edge science in a matter of weeks, compared with the years-long process of analysing big surveys like these in the past," he adds.

A major milestone in this effort is the first detailed catalogue of more than 380,000 galaxies, which have been classified according to features such as spiral arms, central bars, and tidal tails that infer merging galaxies. The catalogue is created by the 'Zoobot' AI algorithm. During an intensive one-month campaign on Galaxy Zoo last year, 9976 human volunteers worked together to teach Zoobot to recognise galaxy features by classifying Euclid images.

This first catalogue released today represents just 0.4% of the total number of galaxies of similar resolution expected to be imaged over Euclid's lifetime. The final catalogue will present the detailed morphology of at least an order of magnitude more galaxies than ever measured before, helping scientists answer questions like how spiral arms form and how supermassive black holes grow.

"We're looking at galaxies from inside to out, from how their internal structures govern their evolution to how the external environment shapes their transformation over time," adds Clotilde.

"Euclid is a goldmine of data and its impact will be far-reaching, from galaxy evolution to the bigger-picture cosmology goals of the mission."

Gravitational lensing discovery engine

Light travelling towards us from distant galaxies is bent and distorted by normal and dark matter in the foreground. This effect is called gravitational lensing and it is one of the tools that Euclid uses to reveal how dark matter is distributed through the Universe. When the distortions are very apparent, it is known as 'strong lensing', which can result in features such as Einstein rings, arcs, and multiple imaged lenses.

Using an initial sweep by AI models, followed by citizen science inspection, expert vetting and modelling, a first catalogue of 500 galaxy-galaxy strong lens candidates is released today, almost all of which were previously unknown. This type of lensing happens when a foreground galaxy and its halo of dark matter act as a lens, distorting the image of a background galaxy along the line of sight towards Euclid.

With the help of these models, Euclid will capture some 7000 candidates in the major cosmology data release planned for the end of 2026, and in the order of 100,000 galaxy-

galaxy strong lenses by the end of the mission, around 100 times more than currently known.
Euclid will also be able to measure 'weak' lensing, when the distortions of background sources are much smaller. Such subtle distortions can only be detected by analysing large numbers of galaxies in a statistical way. In the coming years, Euclid will measure the distorted shapes of billions of galaxies over 10 billion years of cosmic history, thus providing a 3D view of the distribution of dark matter in our Universe.
"Euclid is very quickly covering larger and larger areas of the sky thanks to its unprecedented surveying capabilities," says Pierre Ferruit, ESA's Euclid mission manager, who is based at ESA's European Space Astronomy Centre (ESAC) in Spain, home of the Astronomy Science Archive where Euclid's data will be made available.
"This data release highlights the incredible potential we have by combining the strengths of Euclid, AI, citizen science and experts into a single discovery engine that will be essential in tackling the vast volume of data returned by Euclid."

Notes

As of 19 March 2025, Euclid has observed about 2000 square degrees, approximately 14% of the total survey area (14 000 square degrees). The three deep fields together comprise 63.1 square degrees.
Euclid 'quick' releases, such as the one of 19 March, are of selected areas, intended to demonstrate the data products to be expected in the major data releases that follow, and to allow scientists to sharpen their data analysis tools in preparation. The mission's first cosmology data will be released to the community in October 2026. Data accumulated over additional, multiple passes of the deep field locations will be included in the 2026 release.

About Euclid

Euclid was launched in July 2023 and started its routine science observations on 14 February 2024. In November 2023 and May 2024, the world got its first glimpses of the quality of Euclid's images, and in October 2024 the first piece of its great map of the Universe was released.
Euclid is a European mission, built and operated by ESA, with contributions from its Member States and NASA. The Euclid Consortium -- consisting of more than 2000 scientists from 300 institutes in 15 European countries, the USA, Canada and Japan -- is responsible for providing the scientific instruments and scientific data analysis. ESA selected Thales Alenia Space as prime contractor for the construction of the satellite and its service module, with Airbus Defence and Space chosen to develop the payload module, including the telescope. NASA provided the detectors of the Near-Infrared Spectrometer and Photometer, NISP. Euclid is a medium-class mission in ESA's Cosmic Vision Programme.

- ❖ Oxygen discovered in most distant known galaxy

Date: March 20, 2025
Source: ESO

This is an artist's impression of JADES-GS-z14-0, which as of today is the most distant confirmed galaxy. Galaxies in the early Universe tend to be clumpy and irregular. Supernova explosions in this galaxy would have spread heavy elements forged inside stars, like oxygen, which has been now detected with the Atacama Large Millimetre/submillimetre Array (ALMA).

Credit:

ESO/M. Kornmesser

Two different teams of astronomers have detected oxygen in the most distant known galaxy, JADES-GS-z14-0. The discovery, reported in two separate studies, was made possible thanks to the Atacama Large Millimetre/submillimetre Array (ALMA), in which the European Southern Observatory (ESO) is a partner. This record-breaking detection is making astronomers rethink how quickly galaxies formed in the early Universe. Discovered last year, JADES-GS-z14-0 is the most distant confirmed galaxy ever found: it is so far away, its light took 13.4 billion years to reach us, meaning we see it as it was when the Universe was less than 300 million years old, about 2% of its present age. The new oxygen detection with ALMA, a telescope array in Chile's Atacama Desert, suggests the

galaxy is much more chemically mature than expected.
"It is like finding an adolescent where you would only expect babies," says Sander Schouws, a PhD candidate at Leiden Observatory, the Netherlands, and first author of the Dutch-led study, now accepted for publication in The Astrophysical Journal. "The results show the galaxy has formed very rapidly and is also maturing rapidly, adding to a growing body of evidence that the formation of galaxies happens much faster than was expected."
Galaxies usually start their lives full of young stars, which are made mostly of light elements like hydrogen and helium. As stars evolve, they create heavier elements like oxygen, which get dispersed through their host galaxy after they die. Researchers had thought that, at 300 million years old, the Universe was still too young to have galaxies ripe with heavy elements. However, the two ALMA studies indicate JADES-GS-z14-0 has about 10 times more heavy elements than expected.
"I was astonished by the unexpected results because they opened a new view on the first phases of galaxy evolution," says Stefano Carniani, of the Scuola Normale Superiore of Pisa, Italy, and lead author on the paper now accepted for publication in Astronomy & Astrophysics. "The evidence that a galaxy is already mature in the infant Universe raises questions about when and how galaxies formed."
The oxygen detection has also allowed astronomers to make their distance measurements to JADES-GS-z14-0 much more accurate. "The ALMA detection offers an extraordinarily precise measurement of the galaxy's distance down to an uncertainty of just 0.005 percent. This level of precision -- analogous to being accurate within 5 cm over a distance of 1 km -- helps refine our understanding of distant galaxy properties," adds Eleonora Parlanti, a PhD student at the Scuola Normale Superiore of Pisa and author on the Astronomy & Astrophysics study [1].
"While the galaxy was originally discovered with the James Webb Space Telescope, it took ALMA to confirm and precisely determine its enormous distance," [2] says Associate Professor Rychard Bouwens, a member of the team at Leiden Observatory. "This shows the amazing synergy between ALMA and JWST to reveal the formation and evolution of the first galaxies."
Gergö Popping, an ESO astronomer at the European ALMA Regional Centre who did not take part in the studies, says: "I was really surprised by this clear detection of oxygen in JADES-GS-z14-0. It suggests galaxies can form more rapidly after the Big Bang than had previously been thought. This result showcases the important role ALMA plays in unravelling the conditions under which the first galaxies in our Universe formed."
Notes
[1] Astronomers use a measurement known as redshift to determine the distance to extremely distant objects. Previous measurements indicated that the galaxy JADES-GS-z-14-0 was at a redshift between about 14.12 and 14.4. With their oxygen detections, both teams have now narrowed this down to a redshift around 14.18.
[2] The James Webb Space Telescope is a joint project of NASA, the European Space Agency (ESA) and the Canadian Space Agency (CSA).

- Oxygen for Mars

Direct splitting: Electrochemical process uses carbon dioxide to produce oxygen
Date: March 24, 2025
Source: Wiley

To mitigate global climate change, emissions of the primary culprit, carbon dioxide, must be drastically reduced. A newly developed process helps solve this problem: CO_2 is directly split electrochemically into carbon and oxygen. As a Chinese research team reports in the journal *Angewandte Chemie*, oxygen could also be produced in this way under water or in space -- without requiring stringent conditions such as pressure and temperature.
Leafy plants are masters of the art of carbon neutrality: during photosynthesis, they convert CO_2 into oxygen and glucose. Hydrogen atoms play an important role as "mediators." However, the process is not particularly efficient. In addition, the oxygen produced does not come from the CO_2 but from the absorbed water. True splitting of CO_2 is not taking place in plants and also could not be achieved at moderate temperatures by technical means so far.
Ping He, Haoshen Zhou, and their team at Nanjing University, in collaboration with researcher from Fudan University (Shanghai) have now achieved their goal to directly split CO_2 into elemental carbon and oxygen.

Instead of hydrogen, the "mediator" in their method is lithium. The team developed an electrochemical device consisting of a gas cathode with a nanoscale cocatalyst made of ruthenium and cobalt (RuCo) as well as a metallic lithium anode. CO_2 is fed into the cathode and undergoes a two-step electrochemical reduction with lithium. Initially, lithium carbonate Li_2CO_3 is formed, which reacts further to produce lithium oxide Li_2O and elemental carbon. In an electrocatalytic oxidation process, the Li_2O is then converted to lithium ions and oxygen gas O_2. Use of an optimized RuCo catalyst allows for a very high yield of O_2, over 98.6 %, significantly exceeding the efficiency of natural photosynthesis. As well as pure CO_2, successful tests were also carried out with mixed gases containing varying fractions of CO_2, including simulated flue gas, a CO_2/O_2 mixture, and simulated Mars gas. The atmosphere on Mars consists primarily of CO_2, though the pressure is less than 1 % of the pressure of Earth's atmosphere. The simulated Mars atmosphere thus contained a mixture of argon and 1 % CO_2.
If the required power comes from renewable energy, this method paves the way toward carbon neutrality. At the same time, it is a practical, controllable method for the production of O_2 from CO_2 with broad application potential -- from the exploration of Mars and oxygen supply for spacesuits to underwater life support, breathing masks, indoor air purification, and industrial waste treatment.

- Nanomaterials used to measure nuclear reaction on radioactive nuclei produced in neutron star collisions

Date: March 18, 2025
Source: University of Surrey

Credit: Pixabay/CC0 Public Domain

Physicists have measured a nuclear reaction that can occur in neutron star collisions, providing direct experimental data for a process that had previously only been theorised. The study, led by the University of Surrey, provides new insight into how the universe's heaviest elements are forged -- and could even drive advancements in nuclear reactor physics.
Working in collaboration with the University of York, the University of Seville, and TRIUMF, Canada's national particle accelerator centre, the breakthrough marks the first-ever measurement of a weak r-process reaction cross-section using a radioactive ion beam, in this case studying the 94Sr(α,n)97Zr reaction. This is where a radioactive form of strontium (strontium-94) absorbs an alpha particle (a helium nucleus), then emits a neutron and transforms into zirconium-97.
The study has been published as an Editors Suggestion in *Physical Review Letters.*
Dr Matthew Williams, lead author of the study from the University of Surrey, said:
"The weak r-process plays a crucial role in the formation of heavy elements, which astronomers have observed in ancient stars -- celestial fossils that carry the chemical fingerprints of perhaps only one prior cataclysmic event, like a supernovae or neutron star merger. Until now, our understanding of how these elements form has relied on theoretical predictions, but this experiment provides the first real-world data to test those models that involve radioactive nuclei."
The experiment was enabled by the use of novel helium targets. Since helium is a noble gas, meaning it is neither reactive nor solid, researchers at the University of Seville developed an innovative nano-material target, embedding helium inside ultra-thin silicon films to form billions of microscopic helium bubbles, each only a few 10s of nanometres across.
Using TRIUMF's advanced radioactive ion beam technology, the team accelerated short-lived strontium-94 isotopes into these targets, allowing them to measure the nuclear reaction under conditions similar to those found in extreme cosmic environments.
Dr Williams said:
"This is a major achievement for astrophysics and nuclear physics, and the first-time nanomaterials have been used in this way, opening exciting new possibilities for nuclear research.
"Beyond astrophysics, understanding how radioactive nuclei behave is crucial for improving nuclear reactor design. These types of nuclei are constantly produced in nuclear

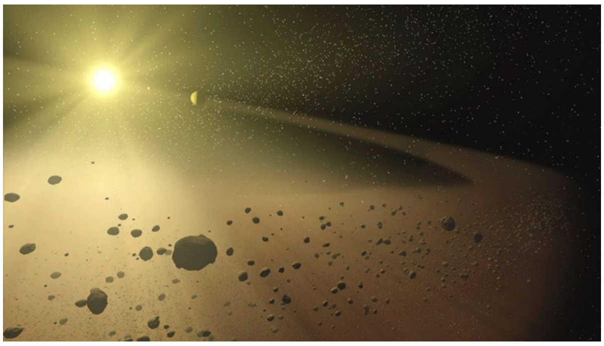
reactors, but until recently, studying their reactions has been extremely difficult. Reactor physics depends on this kind of data to predict how often components need replacing, how long they'll last and how to design more efficient, modern systems."

The next phase of research will apply the findings to astrophysical models, helping scientists to better understand the origins of the heaviest known elements. As researchers continue to explore these processes, their work could deepen our understanding of both the extreme physics of neutron star collisions and practical applications in nuclear technology.

- Meteorites: A geologic map of the asteroid belt

Knowing from what debris field in the asteroid belt our meteorites originate is important for planetary defence efforts against Near Earth Asteroids.

Date: March 18, 2025
Source: SETI Institute



Artist's impression of the main asteroid belt. Astronomers tracked meteorite falls to build a geological map of the asteroid belt. Image Credit: NASA/JPL-Caltech

Where do meteorites of different type come from? In a review paper in the journal Meteoritics & Planetary Science, published online this week, astronomers trace the impact orbit of observed meteorite falls to several previously unidentified source regions in the asteroid belt.

"This has been a decade-long detective story, with each recorded meteorite fall providing a new clue," said meteor astronomer and lead author Peter Jenniskens of the SETI Institute and NASA Ames Research Centre. "We now have the first outlines of a geologic map of the asteroid belt."

Ten years ago, Jenniskens teamed up with astronomer Hadrien Devillepoix of Curtin University and colleagues in Australia to build a network of all-sky cameras in California and Nevada that can capture and track the bright light of meteorites as they hit the Earth's atmosphere. Many institutes and citizen scientists participated in this effort over the years.

"Others built similar networks spread around the globe, which together form the Global Fireball Observatory," said Devillepoix. "Over the years, we have tracked the path of 17 recovered meteorite falls."

Many more fireballs were tracked by doorbell and dashcam video cameras from citizen scientists around the globe and by other dedicated networks.

"Altogether, this quest has yielded 75 laboratory-classified meteorites with an impact orbit tracked by video and photographic cameras," said Jenniskens. "That proves to be enough to start seeing some patterns in the direction from which the meteorites approach Earth."

Most meteorites originate from the asteroid belt, a region between Mars and Jupiter where over a million asteroids larger than 1 kilometre circle the Sun. Those rocks originate from a small number of larger asteroids that broke in collisions, the debris fields of which litter the region. Even today, asteroids collide to create debris fields within these asteroid families, called clusters.

"We now see that 12 of the iron-rich ordinary chondrite meteorites (H chondrites) originated from a debris field called "Koronis," which is located low in the pristine main belt," said Jenniskens. "These meteorites arrived from low-inclined orbits with orbital periods consistent with this debris field."

Astronomers can measure how long ago these rocks were dug up from below the asteroid's surface by measuring the level of radioactive elements created by exposure to cosmic rays. This cosmic-ray exposure age of the meteorites proves to match the dynamical age of some of the asteroid debris fields.

Scientists determine the dynamical age of debris fields by measuring how much asteroids of different size have spread over time.

"By measuring the cosmic ray exposure age of meteorites, we can determine that three of these twelve meteorites originated from the Karin cluster in Koronis, which has a dynamical age of 5.8 million years, and two came from the Koronis2 cluster, with a dynamical age of 10-15 million years," said Jenniskens. "One other meteorite may well measure the age of the Koronis3 cluster: about 83 million years."

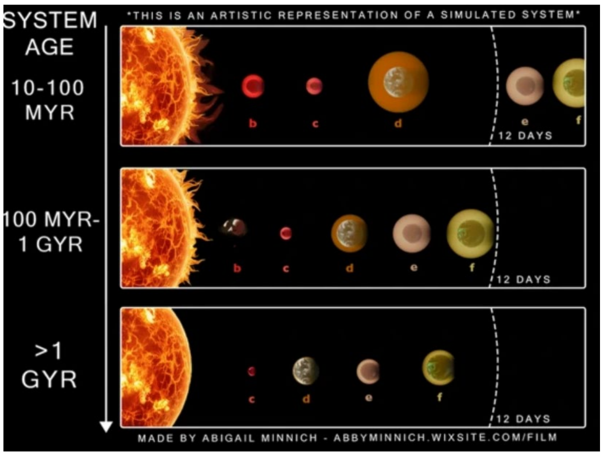
Jenniskens and Devillepoix also found a group of H-chondrites on steep orbits that appear to originate from the Nele asteroid family in the central main belt, which has a dynamical age of about 6 million years. The nearby 3:1 mean-motion resonance with Jupiter can pump up the inclinations to those observed. A third group of H chondrites that have an exposure age of about 35 million years originated from the inner main belt.
"In our opinion, these H chondrites originated from the Massalia asteroid family low in the inner main belt because that family has a cluster of about that same dynamical age," said Jenniskens. "The asteroid that created that cluster, asteroid (20) Massalia, is an H chondrite type parent body."
Jenniskens and Devillepoix find that low iron (L chondrite) and very low iron (LL chondrite) meteorites come to us primarily from the inner main belt. Scientists have long linked the LL chondrites to the Flora asteroid family on the inner side of the asteroid belt, and they have confirmed that connection.
"We propose that the L chondrites originated from the Hertha asteroid family, located just above the Massalia family," said Jenniskens. "Asteroid Hertha doesn't look anything like its debris. Hertha is covered by dark rocks that were shock-blackened, indicative of an unusually violent collision. The L chondrites experienced a very violent origin 468 million years ago when these meteorites showered Earth in such numbers that they can be found in the geologic record."
Knowing from what debris field in the asteroid belt our meteorites originate is important for planetary defence efforts against Near Earth Asteroids. An approaching asteroid's orbit can provide clues to its origin in the asteroid belt in the same way as meteorite orbits.
"Near Earth Asteroids do not arrive on the same orbits as meteorites, because it takes longer for these to evolve to Earth." said Jenniskens. "But they do come from some of the same asteroid families."
Jenniskens and Devillepoix discuss the links of several other meteorite types to their source regions. Not all assignments are certain.
"We are proud about how far we have come, but there is a long way to go," said Jenniskens, "Like the first cartographers who traced the outline of Australia, our map reveals a continent of discoveries still ahead when more meteorite falls are recorded."

What's coming next? Asteroids directly meet meteorites when observed in space before impacting Earth and then recovered. Jenniskens guided the recovery of the first such small asteroid in 2008, called asteroid 2008 TC3, and we are about to see a lot more thanks to new astronomical facilities coming online.

- Combination of cosmic processes shapes the size and location of sub-Neptunes

Newly developed tool helps parse data and detect planets smaller than Neptune around young stars, providing insight into their formation

Date: March 17, 2025
Source: Penn State



A combination of cosmic processes shapes the formation of one of the most common types of planets outside of our solar system, a new study finds.

The research team, which included University of Arizona planetary scientists, used data from NASA's Transiting Exoplanet Survey Satellite, or TESS, to study young sub-Neptunes — planets bigger than Earth but smaller than Neptune — that orbit close to their stars.

A combination of cosmic processes shapes the formation of one of the most common types of planets outside of our solar system, according to a new study led by researchers at Penn State. The research team used data from NASA's Transiting Exoplanet Survey Satellite (TESS) to study young sub-Neptunes -- planets bigger than Earth but smaller than Neptune -- that orbit close to their stars. The work provides insights into how these planets might migrate inward or lose their atmosphere during their early stages.
A paper describing the research appeared today March 17 in the *Astronomical Journal.* The findings offer clues about the properties of sub-Neptunes and help address long-standing questions about their origins, the team said.

"The majority of the 5,500 or so exoplanets discovered to date have a very close orbit to their stars, closer than Mercury to our sun, which we call 'close-in' planets," said Rachel Fernandes, President's Postdoctoral Fellow in the Department of Astronomy and Astrophysics at Penn State and leader of the research team. "Many of these are gaseous sub-Neptunes, a type of planet absent from our own solar system. While our gas giants, like Jupiter and Saturn, formed farther from the sun, it's unclear how so many close-in sub-Neptunes managed to survive near their stars, where they are bombarded by intense stellar radiation."

To better understand how sub-Neptunes form and evolve, the researchers turned to planets around young stars, which only recently became observable thanks to TESS.

"Comparing the frequency of exoplanets of certain sizes around stars of different ages can tell us a lot about the processes that shape planet formation," Fernandes said. "If planets commonly form at specific sizes and locations, we should see a similar frequency of those sizes across different ages. If we don't, it suggests that certain processes are changing these planets over time."

Observing planets around young stars, however, has traditionally been difficult. Young stars emit bursts of intense radiation, rotate quickly and are highly active, creating high levels of "noise" that make it challenging to observe planets around them.

"Young stars in their first billion years of life throw tantrums, emitting a ton of radiation," Fernandes explained. "These stellar tantrums cause a lot of noise in the data, so we spent the last six years developing a computational tool called Pterodactyls to see through that noise and actually detect young planets in TESS data."

The research team used Pterodactyls to evaluate TESS data and identify planets with orbital periods of 12 days or less -- for reference, much less than Mercury's 88-day orbit -- with the goal of examining the planet sizes, as well as how the planets were shaped by the radiation from their host stars. Because the team's survey window was 27 days, this allowed them to see two full orbits from potential planets. They focused on planets between a radius of 1.8 and 10 times the size of Earth, allowing the team to see if the frequency of sub-Neptunes is similar or different in young systems versus older systems previously observed with TESS and NASA's retired Kepler Space Telescope.

The researchers found that the frequency of close-in sub-Neptunes changes over time, with fewer sub-Neptunes around stars between 10 and 100 million years of age compared to those between 100 million and 1 billion years of age. However, the frequency of close-in sub-Neptunes is much less in older, more stable systems.

"We believe a variety of processes are shaping the patterns we see in close-in stars of this size," Fernandes said. "It's possible that many sub-Neptunes originally formed further away from their stars and slowly migrated inward over time, so we see more of them at this orbital period in the intermediate age. In later years, it's possible that planets are more commonly shrinking when radiation from the star essentially blows away its atmosphere, a process called atmospheric mass loss that could explain the lower frequency of sub-Neptunes. But it's likely a combination of cosmic processes shaping these patterns over time rather than one dominant force."

The researchers said they would like to expand their observation window with TESS to observe planets with longer orbital periods. Future missions like the European Space Agency's PLATO may also allow the research team to observe planets of smaller sizes, similar to that of Mercury, Venus, Earth and Mars. Expanding their analysis to smaller and more distant planets could help the researchers refine their tool and provide additional information about how and where planets form.

Additionally, NASA's James Webb Space Telescope could permit the characterization of the density and composition of individual planets, which Fernandes said could give additional hints to where they formed.

"Combining studies of individual planets with the population studies like we conducted here would give us a much better picture of planet formation around young stars," Fernandes said. "The more solar systems and planets we discover, the more we realize that our solar system isn't really the template; it's an exception. Future missions might enable us to find smaller planets around young stars and give us a better picture of how planetary systems form and evolve with time, helping us better understand how our solar system, as we know it today, came to be."

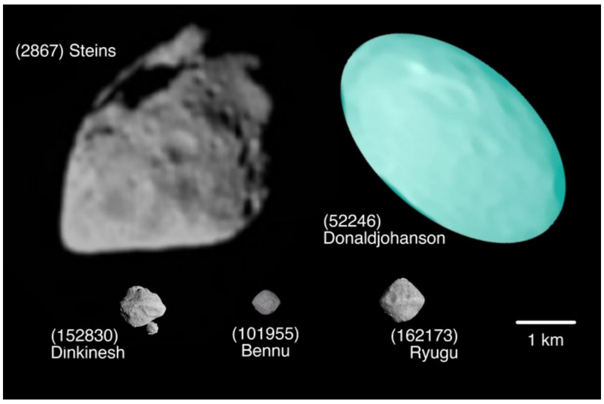
In addition to Fernandes, the research team at Penn State includes Rebekah Dawson, Shaffer Career Development Professor in Science and professor of astronomy and astrophysics at the time of the research and now a physical scientist at NASA. The research team also includes Galen J. Bergsten, Ilaria Pascucci, Kevin K. Hardegree-Ullman, Tommi T. Koskinen and Katia Cunha at the University of Arizona; Gijs Mulders at Pontifical Catholic University of Chile; Steven Giacalone, Eric Mamajek, Kyle Pearson, David Ciardi, Preethi Karpoor, Jessie Christiansen and Jon Zink at the California Institute of Technology; James Rogers at the University of Cambridge, Los Angeles; Akash Gupta at Princeton University; Kiersten Boley at the Carnegie Institution for Science; Jason Curtis at Columbia University; Sabina Sagynbayeva at Stony Brook University; Sakhee Bhure at the University of Southern Queensland in Australia; and Gregory Feiden at the University of North Georgia.

Funding from NASA, including through support of the "Alien Earths" grant; Chile's National Fund for Scientific and Technological Development; and the U.S. National Science Foundation supported this research. Additional support was provided by the Penn State Centre for Exoplanets and Habitable Worlds and the Penn State Extraterrestrial Intelligence Centre. Computations for this research were performed with Penn State's University's Institute for Computational and Data Sciences' Roar supercomputer.

- ❖ Age of upcoming asteroid flyby target

NASA's Lucy mission will encounter asteroid Donaldjohanson on April 20, 2025

Date: March 17, 2025
Source: Southwest Research Institute



This artist's concept compares the approximate size of Lucy's next asteroid target, Donaldjohanson, to the smallest main belt asteroids previously visited by spacecraft — Dinkinesh, visited by Lucy in November 2023, and Steins — as well as two recently explored near-Earth asteroids, Bennu and Ryugu.

Credits: SwRI/ESA/OSIRIS/NASA/Goddard/Johns Hopkins APL/NOIRLab/University of Arizona/JAXA/University of Tokyo & Collaborators

New Southwest Research Institute-led modelling indicates the main belt asteroid (52246) Donaldjohanson may have formed about 150 million years ago when a larger parent asteroid broke apart; its orbit and spin properties have undergone significant evolution since. When NASA's Lucy spacecraft flies by this approximately three-mile-wide space rock on April 20, 2025, the data collected could provide independent insights on such processes based on its shape, surface geology and cratering history.

"Based on ground-based observations, Donaldjohanson appears to be a peculiar object," said SwRI's Dr. Simone Marchi, deputy principal investigator of the SwRI-led Lucy mission and lead author of research published in The Planetary Science Journal. "Understanding the formation of Donaldjohanson could help explain its peculiarities."

"Data indicates that it could be quite elongated and a slow rotator, possibly due to thermal torques that have slowed its spin over time," added David Vokrouhlický, a professor at the Charles University, Prague, and co-author of the research.

Lucy's target is a common type of asteroid, composed of silicate rocks and perhaps containing clays and organic matter. The new paper indicates that Donaldjohanson is likely a member of the Erigone collisional asteroid family, a group of asteroids on similar orbits that was created when a larger parent asteroid broke apart. The family originated in the inner main belt not very far from the source regions of near-Earth asteroids (101955) Bennu and (162173) Ryugu, recently visited respectively by NASA's OSIRIS-REx and JAXA's Hayabusa2 missions.

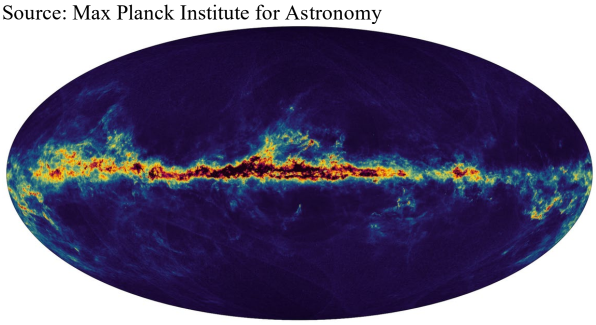
"We can hardly wait for the flyby because, as of now, Donaldjohanson's characteristics appear very distinct from Bennu and Ryugu. Yet, we may uncover unexpected connections," Marchi said.

Donaldjohanson is named for the palaeontologist who discovered Lucy, the fossilized skeleton of an early hominin found in Ethiopia in 1974, which is how the Lucy mission got its name. Just as the Lucy fossil provided unique insights into the origin of humanity, the Lucy mission promises to revolutionize our knowledge of the origin of

humanity's home world. Donaldjohanson is the only named asteroid yet to be visited while its namesake is still living.
"Lucy is an ambitious NASA mission, with plans to visit 11 asteroids in its 12-year mission to tour the Trojan asteroids that are located in two swarms leading and trailing Jupiter," said SwRI's Dr. Hal Levison, who is the principal investigator of the mission. "Encounters with main belt asteroids not only provide a close-up view of those bodies but also allow us to perform engineering tests of the spacecraft's innovative navigation system before the main event to study the Trojans. These relics are effectively fossils of the planet formation process, holding vital clues to deciphering the history of our solar system."
Lucy's principal investigator is based out of the Boulder, Colorado, branch of Southwest Research Institute, headquartered in San Antonio. NASA's Goddard Space Flight Centre in Greenbelt, Maryland, provides overall mission management, systems engineering, and safety and mission assurance. Lockheed Martin Space in Littleton, Colorado, built the spacecraft. Lucy is the 13th mission in NASA's Discovery Program. NASA's Marshall Space Flight Centre in Huntsville, Alabama, manages the Discovery Program for the agency's Science Mission Directorate in Washington.

- Detailed map of dust in the Milky Way

Date: March 13, 2025
Source: Max Planck Institute for Astronomy



Astronomers from the Max Planck Institute for Astronomy have constructed the first detailed 3D map of the properties of cosmic dust in our home galaxy. For their map, the astronomers used 130 million spectra from ESA's Gaia mission, results from the LAMOST spectral survey, and machine learning. Dust makes distant astronomical objects appear more reddish and dimmer than they really are, so the new map will be an important tool for astronomers to make sense of their observations. The study has also revealed unusual properties of cosmic dust that will lead to further research.
When we observe distant celestial objects, there is a possible catch: Is that star I am observing really as reddish as it appears? Or does the star merely look reddish, since its light has had to travel through a cloud of cosmic dust to reach our telescope? For accurate observations, astronomers need to know the amount of dust between them and their distant targets. Not only does dust make objects appear reddish ("reddening"), it also makes them appear fainter than they really are ("extinction"). It's like we are looking out into space through a dirty window. Now, two astronomers have published a 3D map that documents the properties of dust all around us in unprecedented detail, helping us make sense of what we observe.
Behind this is the fact that, fortunately, when looking at stars, there is a way of reconstructing the effect of dust. Cosmic dust particles do not absorb and scatter light evenly across all wavelengths. Instead, they absorb light more strongly at shorter wavelengths (towards the blue end of the spectrum), and less strongly at longer wavelengths (towards the red end). The wavelength-dependence can be plotted as an "extinction curve," and its shape provides information not only about the composition of the dust, but also about its local environment, such as the amount and properties of radiation in the various regions of interstellar space.

Retrieving dust information from 130 million spectra

This is the kind of information used by Xiangyu Zhang, a PhD student at the Max Planck Institute for Astronomy (MPIA), and Gregory Green, an independent research group leader (Sofia Kovalevskaja Group) at MPIA and Zhang's PhD advisor, to construct the most detailed 3D map yet of the properties of dust in the Milky Way galaxy. Zhang and Green turned to data from ESA's Gaia mission, which was a 10.5-year-effort to obtain extremely accurate measurements of positions, motions and additional properties for more than a billion stars in our Milky Way and in our nearest galactic neighbours, the Magellanic Clouds. The third data release (DR3) of the Gaia mission, published in June 2022, provides 220 million spectra, and a quality check told Zhang and Green that about 130 million of those would be suitable for their search for dust.

The Gaia spectra are low-resolution, that is, the way that they separate light into different wavelength regions is comparatively coarse. The two astronomers found a way around that limitation: For 1% of their chosen stars, there is high-resolution spectroscopy from the LAMOST survey operated by the National Astronomical Observatories of China. This provides reliable information about the basic properties of the stars in question, such as their surface temperatures, which determines what astronomers call a star's "spectral type."

Reconstructing a 3D map

Zhang and Green trained a neural network to generate model spectra based on a star's properties and the properties of the intervening dust. They compared the results to 130 million suitable spectra from Gaia, and used statistical ("Bayesian") techniques to deduce the properties of the dust between us and those 130 million stars.

The results allowed the astronomers to reconstruct the first detailed, three-dimensional map of the extinction curve of dust in the Milky Way. This map was made possible by Zhang and Green's measurement of the extinction curve towards an unprecedented number of stars -- 130 million, compared to previous works, which contained approximately 1 million measurements.

But dust is not just a nuisance for astronomers. It is important for star formation, which occurs in giant gas clouds shielded by their dust from the surrounding radiation. When stars form, they are surrounded by disks of gas and dust, which are the birthplaces of planets. The dust grains themselves are the building blocks for what will eventually become the solid bodies of planets like our Earth. In fact, within the interstellar medium of our galaxy, most of the elements heavier than hydrogen and helium are locked up in interstellar dust grains.

Unexpected properties of cosmic dust

The new results not only produce an accurate 3D map. They have also turned up a surprising property of interstellar dust clouds. Previously, it had been expected that the extinction curve should become flatter (less dependent on wavelength) for regions with a higher dust density. "Higher density," of course, is in this case still very little: approximately ten billionth billionth grams of dust per cubic meter, equivalent to just 10 kg of dust in a sphere with Earth's radius. In such regions, dust grains tend to grow in size, which changes the overall absorption properties.

Instead, the astronomers found that in areas of intermediate density, the extinction curve actually becomes steeper, with smaller wavelengths absorbed much more effectively than longer ones. Zhang and Green surmise that the steepening might be caused by the growth not of dust, but of a class of molecules called polycyclic aromatic hydrocarbons (PAHs), the most abundant hydrocarbons in the interstellar medium, which may even have played a role in the origin of life. They have already set out to test their hypothesis with future observations.