South Downs Mercury

The monthly circular of South Downs Astronomical Society
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Main Speaker Trevor Pitt weather Forecasting for Astronomers

Last month's Covid-19 rules still apply at the planetarium

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- Mars habitability limited by its small size, isotope study suggests

Date: September 20, 2021
Source: Washington University in St. Louis

Mars illustration (stock image; elements furnished by NASA).
Credit: © dimazel / stock.adobe.com

Water is essential for life on Earth and other planets, and scientists have found ample evidence of water in Mars' early history. But Mars has no liquid water on its surface today. New research from Washington University in St. Louis suggests a fundamental reason: Mars may be just too small to hold onto large amounts of water.

Remote sensing studies and analyses of Martian meteorites dating back to the 1980s posit that Mars was once water-rich, compared with Earth. NASA's Viking orbiter spacecraft -- and, more recently, the Curiosity and Perseverance rovers on the ground -- returned dramatic images of Martian landscapes marked by river valleys and flood channels.

Despite this evidence, no liquid water remains on the surface. Researchers proposed many possible explanations, including a weakening of Mars' magnetic field that could have resulted in the loss of a thick atmosphere.

But a study published the week of Sept. 20 in the *Proceedings of the National Academy of Sciences* suggests a more fundamental reason why today's Mars looks so drastically different from the "blue marble" of Earth.

"Mars' fate was decided from the beginning," said Kun Wang, assistant professor of earth and planetary sciences in Arts & Sciences at Washington University, senior author of the study. "There is likely a threshold on the size requirements of rocky planets to retain enough water to enable habitability and plate tectonics, with mass exceeding that of Mars."

For the new study, Wang and his collaborators used stable isotopes of the element potassium (K) to estimate the presence, distribution and abundance of volatile elements on different planetary bodies.

Potassium is a moderately volatile element, but the scientists decided to use it as a kind of tracer for more volatile elements and compounds, such as water. This is a relatively new method that diverges from previous attempts to use potassium-to-thorium (Th) ratios gathered by remote sensing and chemical analysis to determine the number of volatiles Mars once had. In previous research, members of the research group used a potassium tracer method to study the formation of the moon.

Wang and his team measured the potassium isotope compositions of 20 previously confirmed Martian meteorites, selected to be representative of the bulk silicate composition of the red planet.

Using this approach, the researchers determined that Mars lost more potassium and

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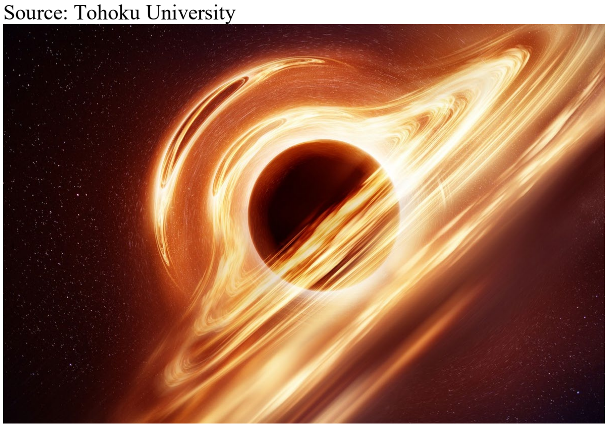
other volatiles than Earth during its formation, but retained more of these volatiles than the moon and asteroid 4-Vesta, two much smaller and drier bodies than Earth and Mars.
The researchers found a well-defined correlation between body size and potassium isotopic composition.
"The reason for far lower abundances of volatile elements and their compounds in differentiated planets than in primitive undifferentiated meteorites has been a longstanding question," said Katharina Lodders, research professor of earth and planetary sciences at Washington University, a co-author of the study. "The finding of the correlation of K isotopic compositions with planet gravity is a novel discovery with important quantitative implications for when and how the differentiated planets received and lost their volatiles."
"Martian meteorites are the only samples available to us to study the chemical makeup of the bulk Mars," Wang said. "Those Martian meteorites have ages varying from several hundred million to 4 billion years and recorded Mars' volatile evolution history. Through measuring the isotopes of moderately volatile elements, such as potassium, we can infer the degree of volatile depletion of bulk planets and make comparisons between different solar system bodies.
"It's indisputable that there used to be liquid water on the surface of Mars, but how much water in total Mars once had is hard to quantify through remote sensing and rover studies alone," Wang said. "There are many models out there for the bulk water content of Mars. In some of them, early Mars was even wetter than the Earth. We don't believe that was the case."
Zhen Tian, a graduate student in Wang's laboratory and a McDonnell International Academy Scholar, is first author of the paper. Postdoctoral research associate Piers Koefoed is a co-author, as is Hannah Bloom, who graduated from Washington University in 2020. Wang and Lodders are faculty fellows of the university's McDonnell Centre for the Space Sciences.
The findings have implications for the search for life on other planets besides Mars, the researchers noted.
Being too close to the sun (or, for exoplanets, being too close to their star) can affect the number of volatiles that a planetary body can retain. This distance-from-star measurement is often factored into indexes of "habitable zones" around stars.
"This study emphasizes that there is a very limited size range for planets to have just enough but not too much water to develop a habitable surface environment," said Klaus Mezger of the Centre for Space and Habitability at the University of Bern, Switzerland, a co-author of the study. "These results will guide astronomers in their search for habitable exoplanets in other solar systems."
Wang now thinks that, for planets that are within habitable zones, planetary size probably should be more emphasized and routinely considered when thinking about whether an exoplanet could support life.
"The size of an exoplanet is one of the parameters that is easiest to determine," Wang said. "Based on size and mass, we now know whether an exoplanet is a candidate for life, because a first-order determining factor for volatile retention is size."

- Gamma rays and neutrinos from mellow supermassive black holes

Date: September 24, 2021
Source: Tohoku University

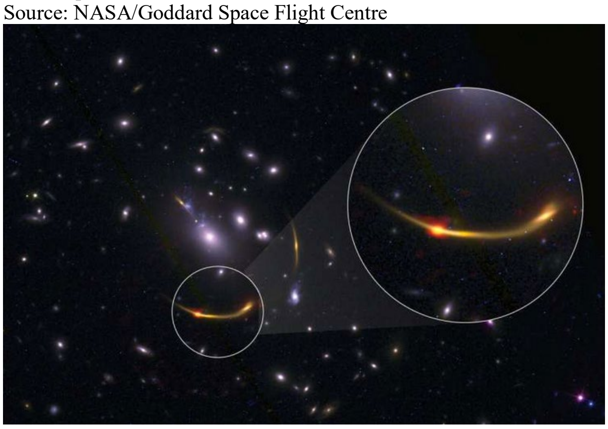


The Universe is filled with energetic particles, such as X rays, gamma rays, and neutrinos. However, most of the high-energy cosmic particles' origins remain unexplained.
Now, an international research team has proposed a scenario that explains these; black holes with low activity act as major factories of high-energy cosmic particles.
Details of their research were published in the journal *Nature Communications*.
Gamma rays are high-energy photons that are many orders of magnitude more energetic than visible light. Space satellites have detected cosmic gamma rays with energies of megaelectron to gigaelectron volts.
Neutrinos are subatomic particles whose mass is nearly zero. They rarely interact with ordinary matter. Researchers at the IceCube

Neutrino Observatory have also measured high-energy cosmic neutrinos.
Both gamma rays and neutrinos should be created by powerful cosmic-ray accelerators or surrounding environments in the Universe. However, their origins are still unknown. It is widely believed that active supermassive black holes (so-called active galactic nuclei), especially those with powerful jets, are the most promising emitters of high-energy gamma rays and neutrinos. However, recent studies have revealed that they do not explain the observed gamma rays and neutrinos, suggesting that other source classes are necessary.
The new model shows that not only active black holes but also non-active, "mellow" ones are important, acting as gamma-ray and neutrino factories.
All galaxies are expected to contain supermassive black holes at their centres. When matter falls into a black hole, a huge amount of gravitational energy is released. This process heats the gas, forming high-temperature plasma. The temperature can reach as high as tens of billions of Celsius degrees for low-accreting black holes because of inefficient cooling, and the plasma can generate gamma rays in the megaelectron volt range.
Such mellow black holes are dim as individual objects, but they are numerous in the Universe. The research team found that the resulting gamma rays from low-accreting supermassive black holes may contribute significantly to the observed gamma rays in the megaelectron volt range.
In the plasma, protons can be accelerated to energies roughly 10,000 times higher than those achieved by the Large Hadron Collider -- the largest human-made particle accelerator. The sped-up protons produce high-energy neutrinos through interactions with matter and radiation, which can account for the higher-energy part of the cosmic neutrino data. This picture can be applied to active black holes as demonstrated by previous research. The supermassive black holes including both active and non-active galactic nuclei can explain a large fraction of the observed IceCube neutrinos in a wide energy range.
Future multi-messenger observational programs are crucial to identify the origin of cosmic high-energy particles. The proposed scenario predicts gamma-ray counterparts in the megaelectron volt range to the neutrino sources. Most of the existing gamma-ray detectors are not tuned to detect them; but future gamma-ray experiments, together with next-generation neutrino experiments, will be able to detect the multi-messenger signals.

- Hubble finds early, massive galaxies running on empty

Date: September 22, 2021
Source: NASA/Goddard Space Flight Centre



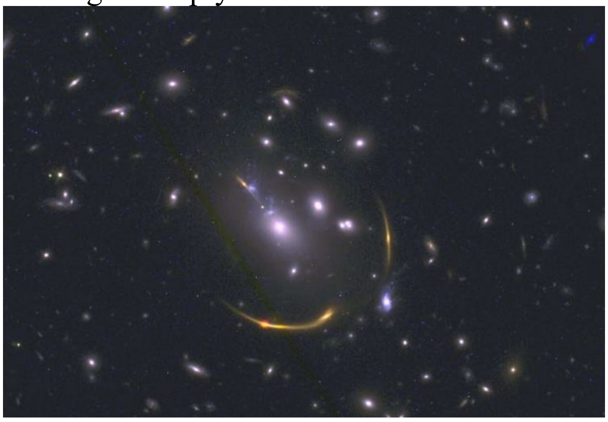
This composite image of galaxy cluster MACSJ 0138 shows data from the Atacama Large Millimetre/submillimetre Array (ALMA) and NASA’s Hubble Space Telescope. The magnified section shows a bright orange/red dot, which traces cold dust observed in radio using ALMA. This cold dust helps scientists to understand, by inference, the amount of cold hydrogen gas—required for the formation of stars—present in the galaxies in the cluster. Credit: ALMA (ESO/NAOJ/NRAO)/S. Dagnello (NRAO), STScI, K. Whitaker et al

Early massive galaxies—those that formed in the 3 billion years following the Big Bang—should have contained large amounts of cold hydrogen gas, the fuel required to make stars. But scientists observing the early universe with the Atacama Large Millimetre/submillimetre Array (ALMA) and the Hubble Space Telescope have spotted something strange: a half-dozen early massive galaxies that ran out of fuel. The results of the research are published today in *Nature*.
Known as "quenched" galaxies—or galaxies that have shut down star formation—the six high-redshift galaxies that were selected for observation from the REQUIEM survey are inconsistent with what astronomers expect of the early universe.
"The most massive galaxies in the universe lived fast and furious, creating their stars in a remarkably short amount of time. Gas, the fuel of star formation, should be plentiful at these early times in the universe," said Kate Whitaker, lead author on the study, and

assistant professor of astronomy at the University of Massachusetts, Amherst. "We originally believed that these quenched galaxies hit the brakes just a few billion years after the Big Bang. In our new research, we've concluded that early galaxies didn't actually put the brakes on, but rather, they were running on empty."

To better understand how the galaxies formed and died, the team observed them using Hubble, which revealed details about the stars residing in the galaxies. Concurrent observations with ALMA revealed the galaxies' continuum emission—a tracer of dust—at millimetre wavelengths, allowing the team to infer the amount of gas in the galaxies.

The use of the two telescopes is by careful design, as the purpose of REQUIEM is to use strong gravitational lensing as a natural telescope to observe dormant galaxies with higher spatial resolution. This, in turn, gives scientists a clear view of galaxies' internal goings-on, a task often impossible with those running on empty.



This composite image of galaxy cluster MACSJ 0138 shows data from the Atacama Large Millimetre/submillimetre Array (ALMA) and NASA's Hubble Space Telescope, as observed by REsolving QUIEscent Magnified galaxies at high redshift, or the REQUIEM survey. The early massive galaxies studied by REQUIEM were found to be lacking in cold hydrogen gas, the fuel required to form stars. Credit: ALMA (ESO/NAOJ/NRAO)/S. Dagnello (NRAO), STScI, K. Whitaker et al

"If a galaxy isn't making many new stars it gets very faint very fast so it is difficult or impossible to observe them in detail with any individual telescope. REQUIEM solves this by studying galaxies that are gravitationally lensed, meaning their light gets stretched and magnified as it bends and warps around other galaxies much closer to the Milky Way," said Justin Spilker, a co-author on the new study, and a NASA Hubble postdoctoral fellow at the University of Texas at Austin. "In this way, gravitational lensing, combined with the resolving power and sensitivity of Hubble and ALMA, acts as a natural telescope and makes these dying galaxies appear bigger and brighter than they are in reality, allowing us to see what's going on and what isn't."

The new observations showed that the cessation of star formation in the six target galaxies was not caused by a sudden inefficiency in the conversion of cold gas to stars. Instead, it was the result of the depletion or removal of the gas reservoirs in the galaxies. "We don't yet understand why this happens, but possible explanations could be that either the primary gas supply fuelling the galaxy is cut off, or perhaps a supermassive black hole is injecting energy that keeps the gas in the galaxy hot," said Christina Williams, an astronomer at the University of Arizona and co-author on the research. "Essentially, this means that the galaxies are unable to refill the fuel tank, and thus, unable to restart the engine on star production."

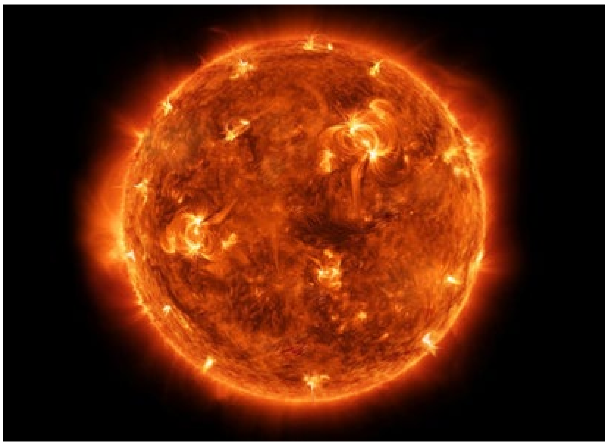
The study also represents a number of important firsts in the measurement of early massive galaxies, synthesizing information that will guide future studies of the early universe for years to come. "These are the first measurements of the cold dust continuum of distant dormant galaxies, and in fact, the first measurements of this kind outside the local universe," said Whitaker, adding that the new study has allowed scientists to see how much gas individual dead galaxies have. "We were able to probe the fuel of star formation in these early massive galaxies deep enough to take the first measurements of the gas tank reading, giving us a critically missing viewpoint of the cold gas properties of these galaxies."

Although the team now knows that these galaxies are running on empty and that something is keeping them from refilling the tank and from forming new stars, the study represents just the first in a series of inquiries into what made early massive galaxies go, or not. "We still have so much to learn about why the most massive galaxies formed so early in the universe and why they shut down their star formation when so much cold gas was readily available to them," said Whitaker. "The mere fact that these massive beasts of the cosmos formed 100 billion stars within about a billion years and then suddenly shut down their star formation is a mystery we would all love to solve, and REQUIEM has provided the first clue."

- Have we detected dark energy? Scientists say it's a possibility

Date: September 15, 2021
Source: University of Cambridge

Illustration of sun (stock image).
Credit: © sdecoret / stock.adobe.com



Dark energy, the mysterious force that causes the universe to accelerate, may have been responsible for unexpected results from the XENON1T experiment, deep below Italy's Apennine Mountains.

A new study, led by researchers at the University of Cambridge and reported in the journal *Physical Review D*, suggests that some unexplained results from the XENON1T experiment in Italy may have been caused by dark energy, and not the dark matter the experiment was designed to detect.

They constructed a physical model to help explain the results, which may have originated from dark energy particles produced in a region of the Sun with strong magnetic fields, although future experiments will be required to confirm this explanation. The researchers say their study could be an important step toward the direct detection of dark energy.

Everything our eyes can see in the skies and in our everyday world -- from tiny moons to massive galaxies, from ants to blue whales -- makes up less than five percent of the universe. The rest is dark. About 27% is dark matter -- the invisible force holding galaxies and the cosmic web together -- while 68% is dark energy, which causes the universe to expand at an accelerated rate.

"Despite both components being invisible, we know a lot more about dark matter, since its existence was suggested as early as the 1920s, while dark energy wasn't discovered until 1998," said Dr Sunny Vagnozzi from Cambridge's Kavli Institute for Cosmology, the paper's first author. "Large-scale experiments like XENON1T have been designed to directly detect dark matter, by searching for signs of dark matter 'hitting' ordinary matter, but dark energy is even more elusive."

To detect dark energy, scientists generally look for gravitational interactions: the way gravity pulls objects around. And on the largest scales, the gravitational effect of dark energy is repulsive, pulling things away from each other and making the Universe's expansion accelerate.

About a year ago, the XENON1T experiment reported an unexpected signal, or excess, over the expected background. "These sorts of excesses are often flukes, but once in a while they can also lead to fundamental discoveries," said Dr Luca Visinelli, a researcher at Frascati National Laboratories in Italy, a co-author of the study. "We explored a model in which this signal could be attributable to dark energy, rather than the dark matter the experiment was originally devised to detect."

At the time, the most popular explanation for the excess were axions -- hypothetical, extremely light particles -- produced in the Sun. However, this explanation does not stand up to observations, since the amount of axions that would be required to explain the XENON1T signal would drastically alter the evolution of stars much heavier than the Sun, in conflict with what we observe.

We are far from fully understanding what dark energy is, but most physical models for dark energy would lead to the existence of a so-called fifth force. There are four fundamental forces in the universe, and anything that can't be explained by one of these forces is sometimes referred to as the result of an unknown fifth force.

However, we know that Einstein's theory of gravity works extremely well in the local universe. Therefore, any fifth force associated to dark energy is unwanted and must be 'hidden' or 'screened' when it comes to small scales, and can only operate on the largest scales where Einstein's theory of gravity fails to explain the acceleration of the Universe. To hide the fifth force, many models for dark energy are equipped with so-called screening mechanisms, which dynamically hide the fifth force.

Vagnozzi and his co-authors constructed a physical model, which used a type of screening mechanism known as chameleon

screening, to show that dark energy particles produced in the Sun's strong magnetic fields could explain the XENON1T excess.
"Our chameleon screening shuts down the production of dark energy particles in very dense objects, avoiding the problems faced by solar axions," said Vagnozzi. "It also allows us to decouple what happens in the local very dense Universe from what happens on the largest scales, where the density is extremely low."
The researchers used their model to show what would happen in the detector if the dark energy was produced in a particular region of the Sun, called the tachocline, where the magnetic fields are particularly strong.
"It was really surprising that this excess could in principle have been caused by dark energy rather than dark matter," said Vagnozzi. "When things click together like that, it's really special."
Their calculations suggest that experiments like XENON1T, which are designed to detect dark matter, could also be used to detect dark energy. However, the original excess still needs to be convincingly confirmed. "We first need to know that this wasn't simply a fluke," said Visinelli. "If XENON1T actually saw something, you'd expect to see a similar excess again in future experiments, but this time with a much stronger signal."
If the excess was the result of dark energy, upcoming upgrades to the XENON1T experiment, as well as experiments pursuing similar goals such as LUX-Zeplin and PandaX-xT, mean that it could be possible to directly detect dark energy within the next decade.

- ❖ Unveiling galaxies at cosmic dawn that were hiding behind the dust

Scientists serendipitously discover two heavily dust-enshrouded galaxies that formed when the Universe was only 5% of its present age

Date: September 22, 2021
Source: Waseda University

When astronomers peer deep into the night sky, they observe what the Universe looked like a long time ago. Because the speed of light is finite, studying the most distant observable galaxies allows us to glimpse billions of years into the past when the Universe was very young and galaxies had just started to form stars. Studying this "early Universe" is one of the last frontiers in astronomy and is essential for constructing accurate and consistent astrophysics models.
A key goal of scientists is to identify all the galaxies in the first billion years of cosmic history and to measure the rate at which galaxies were growing by forming new stars. Various efforts have been made over the past decades to observe distant galaxies, which are characterized by electromagnetic emissions that become strongly redshifted (shifted towards longer wavelengths) before reaching the Earth. So far, our knowledge of early galaxies has mostly relied on observations with the Hubble Space Telescope (HST) and large ground-based telescopes, which probe their ultra-violet (UV) emission. However, recently, astronomers have started to use the unique capability of the Atacama Large Millimetre/submillimetre Array (ALMA) telescope to study distant galaxies at submillimetre wavelengths. This could be particularly useful for studying dusty galaxies missed in the HST surveys due to the dust absorbing UV emission. Since ALMA observes in submillimetre wavelengths, it can detect these galaxies by observing the dust emissions instead.
In an ongoing large program called REBELS (Reionization-Era Bright Emission Line Survey), astronomers are using ALMA to observe the emissions of 40 target galaxies at cosmic dawn. Using this dataset, they have recently discovered that the regions around some of these galaxies contain more than meets the eye.
While analysing the observed data for two REBELS galaxies, Dr. Yoshinobu Fudamoto of the Research Institute for Science and Engineering at Waseda University, Japan, and the National Astronomical Observatory of Japan (NAOJ), noticed strong emission by dust and singly ionized carbon in positions substantially offset from the initial targets. To his surprise, even highly sensitive equipment like the HST couldn't detect any UV emission from these locations. To understand these mysterious signals, Fudamoto and his colleagues investigated matters further.
In their latest paper published in Nature, they presented a thorough analysis, revealing that these unexpected emissions came from two previously unknown galaxies located near the two original REBELS targets. These galaxies are not visible in the UV or visible wavelengths as they are almost completely obscured by cosmic dust. One of them represents the most distant dust-obscured galaxy discovered so far.

What is most surprising about this serendipitous finding is that the newly discovered galaxies, which formed more than 13 billion years ago, are not strange at all when compared with typical galaxies at the same epoch. "These new galaxies were missed not because they are extremely rare, but only because they are completely dust-obscured," explains Fudamoto. However, it is uncommon to find such "dusty" galaxies in the early period of the Universe (less than 1 billion years after the Big Bang), suggesting that the current census of early galaxy formation is most likely incomplete, and would call for deeper, blind surveys. "It is possible that we have been missing up to one out of every five galaxies in the early Universe so far," Fudamoto adds.

The researchers expect that the unprecedented capability of the James Webb Space Telescope (JWST) and its strong synergy with ALMA would lead to significant advances in this field in the coming years. "Completing our census of early galaxies with the currently missing dust-obscured galaxies, like the ones we found this time, will be one of the main objectives of JWST and ALMA surveys in the near future," states Pascal Oesch from University of Geneva.

Overall, this study constitutes an important step in uncovering when the very first galaxies started to form in the early Universe, which in turn shall help us understand where we are standing today.

- Gigantic cavity in space sheds new light on how stars form

Date: September 22, 2021
Source: Harvard-Smithsonian Centre for Astrophysics

Astronomers analysing 3D maps of the shapes and sizes of nearby molecular clouds have discovered a gigantic cavity in space.

The sphere-shaped void, described today in the *Astrophysical Journal Letters*, spans about 150 parsecs -- nearly 500 light years -- and is located on the sky among the constellations Perseus and Taurus. The research team, which is based at the Centre for Astrophysics | Harvard & Smithsonian, believes the cavity was formed by ancient supernovae that went off some 10 million years ago.

The mysterious cavity is surrounded by the Perseus and Taurus molecular clouds -- regions in space where stars form.

"Hundreds of stars are forming or exist already at the surface of this giant bubble," says Shmuel Bialy, a postdoctoral researcher at the Institute for Theory and Computation (ITC) at the Centre for Astrophysics (CfA) who led the study. "We have two theories -- either one supernova went off at the core of this bubble and pushed gas outward forming what we now call the 'Perseus-Taurus Supershell,' or a series of supernovae occurring over millions of years created it over time."

The finding suggests that the Perseus and Taurus molecular clouds are not independent structures in space. But rather, they formed together from the very same supernova shockwave. "This demonstrates that when a star dies, its supernova generates a chain of events that may ultimately lead to the birth of new stars," Bialy explains.

Mapping Stellar Nurseries

The 3D map of the bubble and surrounding clouds were created using new data from Gaia, a space-based observatory launched by the European Space Agency (ESA).

Descriptions of exactly how 3D maps of the Perseus and Taurus molecular clouds and other nearby clouds were analysed appear in a separate study published today in the *Astrophysical Journal* (ApJ). Both studies make use of a dust reconstruction created by researchers at the Max Planck Institute for Astronomy in Germany.

The maps represent the first-time molecular clouds have been charted in 3D. Previous images of the clouds were constrained to two dimensions.

"We've been able to see these clouds for decades, but we never knew their true shape, depth or thickness. We also were unsure how far away the clouds were," says Catherine Zucker, a postdoctoral researcher at the CfA who led the ApJ study. "Now we know where they lie with only 1 percent uncertainty, allowing us to discern this void between them."

But why map clouds in the first place?

"There are many different theories for how gas rearranges itself to form stars," Zucker explains. "Astronomers have tested these theoretical ideas using simulations in the past, but this is the first time we can use real -- not simulated -- 3D views to compare theory to observation, and evaluate which theories work best."

The Universe at Your Fingertips

The new research marks the first time journals of the American Astronomical Society (AAS) publish astronomy visualizations in

augmented reality. Scientists and the public may interact with the visualization of the cavity and its surrounding molecular clouds by simply scanning a QR code in the paper with their smartphone.
"You can literally make the universe float over your kitchen table," says Harvard professor and CfA astronomer Alyssa Goodman, a co-author on both studies and founder of glue, the data visualization software that was used to create the maps of molecular clouds.
Goodman calls the new publications examples of the "paper of the future" and considers them important steps toward the interactivity and reproducibility of science, which AAS committed to in 2015 as part of their effort to modernize publications.
"We need richer records of scientific discovery," Goodman says. "And current scholarly papers could be doing much better. All of the data in these papers are available online -- on Harvard's Dataverse -- so that anyone can build on our results."
Goodman envisions future scientific articles where audio, video and enhanced visuals are regularly included, allowing all readers to more easily understand the research presented. She says, "It's 3D visualizations like these that can help both scientists and the public understand what's happening in space and the powerful effects of supernovae."

- Part of the Universe's missing matter found

Date: September 16, 2021
Source: CNRS
Galaxies can receive and exchange matter with their external environment thanks to the galactic winds created by stellar explosions. Thanks to the MUSE instrument[1] from the *Very Large Telescope*at the ESO, an international research team, led on the French side by the CNRS and l'Université Claude Bernard Lyon 1[2], has mapped a galactic wind for the first time. This unique observation, which is detailed in a study published in *MNRAS* on 16 September 2021, helped to reveal where some of the Universe's missing matter is located and to observe the formation of a nebula around a galaxy.
Galaxies are like islands of stars in the Universe, and possess ordinary or baryonic matter, which consists of elements from the periodic table, as well as dark matter, whose composition remains unknown. One of the major problems in understanding the formation of galaxies is that approximately 80% of the baryons[3] that make up the normal matter of galaxies is missing. According to models, they were expelled from galaxies into inter-galactic space by the galactic winds created by stellar explosions.
An international team[4], led on the French side by researchers from the CNRS and l'Université Claude Bernard Lyon 1, successfully used the MUSE instrument to generate a detailed map of the galactic wind driving exchanges between a young galaxy in formation and a nebula (a cloud of gas and interstellar dust).
The team chose to observe galaxy *Gal1* due to the proximity of a quasar, which served as a "lighthouse" for the scientists by guiding them toward the area of study. They also planned to observe a nebula around this galaxy, although the success of this observation was initially uncertain, as the nebula's luminosity was unknown.
The perfect positioning of the galaxy and the quasar, as well as the discovery of gas exchange due to galactic winds, made it possible to draw up a unique map. This enabled the first observation of a nebula in formation that is simultaneously emitting and absorbing magnesium -- some of the Universe's missing baryons -- with the *Gal1* galaxy.
This type of normal matter nebula is known in the near Universe, but their existence for young galaxies in formation had only been supposed.
Scientists thus discovered some of the Universe's missing baryons, thereby confirming that 80-90% of normal matter is located outside of galaxies, an observation that will help expand models for the evolution of galaxies.
Notes
1 -- MUSE, which stands for Multi Unit Spectroscopic Explorer, is a 3D spectrograph designed to explore the distant Universe. The Centre de recherché astrophysique de Lyon (CNRS/Université Claude Bernard-Lyon 1/ENS de Lyon) led its construction.
2 -- Researchers from the Centre de recherché astrophysique de Lyon (CNRS/Université Claude Bernard Lyon 1/ENS de Lyon), the Galaxies, étoiles, physique, instrumentation laboratory (CNRS/Observatoire de Paris -- PSL), and the Institut de recherché en astrophysique et planétologie

(CNRS/Université Toulouse III -- Paul Sabatier/CNES) participated in the project.
3 -- Baryons are particles consisting of three quarks, such as protons and neutrons. They make up atoms and molecules as well as all visible structures in the observable Universe (stars, galaxies, galaxy clusters, etc.). The "missing" baryons, which had never before been observed, must be distinguished from dark matter, which consists of non-baryonic matter of an unknown nature.
4 -- Including scientists from Saint Mary's University in Canada, the Institute for Astrophysics at the University of Potsdam in Germany, Leiden University in the Netherlands, the University of Geneva and the Swiss Federal Polytechnic School in Zurich, the Inter-University Centre for Astronomy and Astrophysics in India, and the University of Porto in Portugal.

- Shining a light on Moon’s oldest geologic imprints

Date: September 14, 2021
Source: Curtin University

New Curtin research has found the Moon may have been subjected to much greater impacts from asteroids and other bodies than previously thought, building on our understanding of the Moon's earliest geologic evolution.
Published in *Nature Communications,* the research provides a greater insight of how the oldest impact events on the Moon may have left near-invisible cratering imprints, offering a unique perspective about the evolution of the Earth-Moon system.
Lead researcher Associate Professor Katarina Miljkovic, from Curtin's School of Earth and Planetary Science and the Space Science and Technology Centre, said the craters on the Moon may have looked significantly different if they occurred while the Moon was still cooling, following its formation.
"These large impact craters, often referred to as impact basins, formed during the lunar magma ocean solidification more than four billion years ago, should have produced different looking craters, in comparison to those formed later in geologic history," Associate Professor Miljkovic said.
"A very young Moon had formed with a global magma ocean that cooled over millions of years, to form the Moon we see today. So when asteroids and other bodies hit a softer surface, it wouldn't have left such severe imprints, meaning there would be little geologic or geophysical evidence that impact had occurred."
"The timeframe for the solidification of the lunar magma ocean varies significantly between different studies, but it could have been prolonged enough to experience some of the large impact bombardment history typical for the earliest periods of the solar system evolution.
"As the moon ages and the surface cools, it becomes harder, and the bombardment imprints are a lot more noticeable by remote sensing."
Associate Professor Miljkovic said it remained imperative to understand the bombardment and the cratering record from the earliest epochs of solar system history in order to complete the story of how planets formed and evolved.
By comparing different perspectives of asteroid dynamics and lunar evolution modelling, Associate Professor Miljkovic said her research suggested the Moon may be missing evidence of its earliest crating record.
"In this research, we set out to explain the discrepancy between theory and observations of the lunar crating record," Associate Professor Miljkovic said.
"Translating this finding will help future research understand the impact that the early Earth could have experienced and how it would have affected our planet's evolution."

- Astronomers solve 900-year-old cosmic mystery surrounding Chinese supernova of 1181AD

Date: September 15, 2021
Source: University of Manchester

A 900-year-old cosmic mystery surrounding the origins of a famous supernova first spotted over China in 1181AD has finally been solved, according to an international team of astronomers.
New research published today (September 15, 2021) says that a faint, fast expanding cloud (or nebula), called Pa30, surrounding one of the hottest stars in the Milky Way, known as Parker's Star, fits the profile, location and age of the historic supernova.
There have only been five bright supernovae in the Milky Way in the last millennium (starting in 1006). Of these, the Chinese supernova, which is also known as the 'Chinese Guest Star' of 1181AD has remained a mystery. It was originally seen and documented by Chinese and Japanese astronomers in the 12th century who said it

was as bright as the planet Saturn and remained visible for six months. They also recorded an approximate location in the sky of the sighting, but no confirmed remnant of the explosion has even been identified by modern astronomers. The other four supernovae are all now well known to modern day science and include the famous Crab nebula.

The source of this 12th century explosion remained a mystery until this latest discovery made by a team of international astronomers from Hong Kong, the UK, Spain, Hungary and France, including Professor Albert Zijlstra from The University of Manchester. In the new paper, the astronomers found that the Pa 30 nebula is expanding at an extreme velocity of more than 1,100 km per second (at this speed, traveling from the Earth to the Moon would take only 5 minutes). They use this velocity to derive an age at around 1,000 years, which would coincide with the events of 1181AD.

Prof Zijlstra (Professor in Astrophysics at the University of Manchester) explains: "The historical reports place the guest star between two Chinese constellations, Chuanshe and Huagai. Parker's Star fits the position well. That means both the age and location fit with the events of 1181."

Pa 30 and Parker's Star have previously been proposed as the result of a merger of two White Dwarfs. Such events are thought to lead to a rare and relatively faint type of supernova, called a 'Type Iax supernova'.

Prof Zijlstra added: "Only around 10% of supernovae are of this type and they are not well understood. The fact that SN1181 was faint but faded very slowly fits this type. It is the only such event where we can study both the remnant nebula and the merged star, and also have a description of the explosion itself."

The merging of remnant stars, white dwarfs and neutron stars, give rise to extreme nuclear reactions and form heavy, highly neutron-rich elements such as gold and platinum. Prof. Zijlstra said: "Combining all this information such as the age, location, event brightness and historically recorded 185-day duration, indicates that Parker's star and Pa30 are the counterparts of SN 1181. This is the only Type Iax supernova where detailed studies of the remnant star and nebula are possible. It is nice to be able to solve both a historical and an astronomical mystery."

- ❖ Largest virtual universe free for anyone to explore

Date: September 10, 2021
Source: National Institutes of Natural Sciences

Forget about online games that promise you a "whole world" to explore. An international team of researchers has generated an entire virtual UNIVERSE, and made it freely available on the cloud to everyone.

Uchuu (meaning "Outer Space" in Japanese) is the largest and most realistic simulation of the Universe to date. The Uchuu simulation consists of 2.1 trillion particles in a computational cube an unprecedented 9.63 billion light-years to a side. For comparison, that's about three-quarters the distance between Earth and the most distant observed galaxies. Uchuu will allow us to study the evolution of the Universe on a level of both size and detail inconceivable until now.

Uchuu focuses on the large-scale structure of the Universe: mysterious halos of dark matter which control not only the formation of galaxies, but also the fate of the entire Universe itself. The scale of these structures' ranges from the largest galaxy clusters down to the smallest galaxies. Individual stars and planets aren't resolved, so don't expect to find any alien civilizations in Uchuu. But one way that Uchuu wins big in comparison to other virtual worlds is the time domain; Uchuu simulates the evolution of matter over almost the entire 13.8 billion year history of the Universe from the Big Bang to the present. That is over 30 times longer than the time since animal life first crawled out of the seas on Earth.

Julia F. Ereza, a Ph.D. student at IAA-CSIC who uses Uchuu to study the large-scale structure of the Universe explains the importance of the time domain, "Uchuu is like a time machine: we can go forward, backward and stop in time, we can 'zoom in' on a single galaxy or 'zoom out' to visualize a whole cluster, we can see what is really happening at every instant and in every place of the Universe from its earliest days to the present, being an essential tool to study the Cosmos."

An international team of researchers from Japan, Spain, U.S.A., Argentina, Australia, Chile, France, and Italy created Uchuu using ATERUI II, the world's most powerful supercomputer dedicated to astronomy. Even with all this power, it still took a year to produce Uchuu. Tomoaki Ishiyama, an associate professor at Chiba University who developed the code used to generate Uchuu, explains, "To produce Uchuu we have used ... all 40,200 processors (CPU cores) available exclusively for 48 hours each month. Twenty million supercomputer hours were consumed, and 3 Petabytes of data were generated, the equivalent of 894,784,853 pictures from a 12-megapixel cell phone."

Before you start worrying about download time, the research team used high-performance computational techniques to compress information on the formation and evolution of dark matter haloes in the Uchuu simulation into a 100-terabyte catalogue. This catalogue is now available to everyone on the cloud in an easy to use format thanks to the computational infrastructure skun6 located at the Instituto de Astrofísica de Andalucía (IAA-CSIC), the RedIRIS group, and the Galician Supercomputing Centre (CESGA). Future data releases will include catalogues of virtual galaxies and gravitational lensing maps.

Big Data science products from Uchuu will help astronomers learn how to interpret Big Data galaxy surveys expected in coming years from facilities like the Subaru Telescope and the ESA Euclid space mission.

- Cold planets exist throughout our galaxy, even in the galactic bulge, research suggests

Date: August 30, 2021
Source: Osaka University

Spiral galaxy illustration (stock image).

Credit: © Alexandr Mitiuc / stock.adobe.com

Although thousands of planets have been discovered in the Milky Way, most reside less than a few thousand light years from Earth. Yet our Galaxy is more than 100,000 light years across, making it difficult to investigate the Galactic distribution of planets. But now, a research team has found a way to overcome this hurdle.

In a study published in *The Astrophysical Journal Letters*, researchers led by Osaka University and NASA have used a combination of observations and modelling to determine how the planet-hosting probability varies with the distance from the Galactic centre.

The observations were based on a phenomenon called gravitational microlensing, whereby objects such as planets act as lenses, bending and magnifying the light from distant stars. This effect can be used to detect cold planets similar to Jupiter and Neptune throughout the Milky Way, from the Galactic disk to the Galactic bulge -- the central region of our Galaxy.

"Gravitational microlensing currently provides the only way to investigate the distribution of planets in the Milky Way," says Daisuke Suzuki, co-author of the study. "But until now, little is known mainly because of the difficulty in measuring the distance to planets that are more than 10,000 light years from the Sun."

To solve this problem, the researchers instead considered the distribution of a quantity that describes the relative motion of the lens and distant light source in planetary microlensing. By comparing the distribution observed in microlensing events with that predicted by a Galactic model, the research team could infer the Galactic distribution of planets.

The results show that the planetary distribution is not strongly dependent on the distance from the Galactic centre. Instead, cold planets orbiting far from their stars seem to exist universally in the Milky Way. This includes the Galactic bulge, which has a very different environment to the solar neighbourhood, and where the presence of planets has long been uncertain.

"Stars in the bulge region are older and are located much closer to each other than stars in the solar neighbourhood," explains lead author of the study Naoki Koshimoto. "Our finding that planets reside in both these stellar environments could lead to an improved understanding of how planets form and the history of planet formation in the Milky Way."

According to the researchers, the next step should be to combine these results with measurements of micro lens parallax or lens brightness -- two other important quantities associated with planetary microlensing.

- New mathematical solutions to an old problem in astronomy

Date: August 30, 2021
Source: University of Bern

For millennia, humanity has observed the changing phases of the Moon. The rise and fall of sunlight reflected off the Moon, as it presents its different faces to us, is known as a "phase curve." Measuring phase curves of the Moon and Solar System planets is an ancient branch of astronomy that goes back at least a century. The shapes of these phase curves encode information on the surfaces and atmospheres of these celestial bodies. In modern times, astronomers have measured the phase curves of exoplanets using space telescopes such as Hubble, Spitzer, TESS and CHEOPS. These observations are compared with theoretical predictions. In order to do so, one needs a way of calculating these phase curves. It involves seeking a solution to a difficult mathematical problem concerning the physics of radiation.

Approaches for the calculation of phase curves have existed since the 18th century. The oldest of these solutions goes back to the Swiss mathematician, physicist and astronomer, Johann Heinrich Lambert, who lived in the 18th century. "Lambert's law of reflection" is attributed to him. The problem of calculating reflected light from Solar System planets was posed by the American astronomer Henry Norris Russell in an influential 1916 paper. Another well-known 1981 solution is attributed to the American lunar scientist Bruce Hapke, who built on the classic work of the Indian-American Nobel laureate Subrahmanyan Chandrasekhar in 1960. Hapke pioneered the study of the Moon using mathematical solutions of phase curves. The Soviet physicist Viktor Sobolev also made important contributions to the study of reflected light from celestial bodies in his influential 1975 textbook. Inspired by the work of these scientists, theoretical astrophysicist Kevin Heng of the Centre for Space and Habitability CSH at the University of Bern has discovered an entire family of new mathematical solutions for calculating phase curves. The paper, authored by Kevin Heng in collaboration with Brett Morris from the National Centre of Competence in Research NCCR PlanetS -- which the University of Bern manages together with the University of Geneva -- and Daniel Kitzmann from the CSH, has just been published in *Nature Astronomy*.

Generally applicable solutions

"I was fortunate that this rich body of work had already been done by these great scientists. Hapke had discovered a simpler way to write down the classic solution of Chandrasekhar, who famously solved the radiative transfer equation for isotropic scattering. Sobolev had realised that one can study the problem in at least two mathematical coordinate systems." Sara Seager brought the problem to Heng's attention by her summary of it in her 2010 textbook.

By combining these insights, Heng was able to write down mathematical solutions for the strength of reflection (the albedo) and the shape of the phase curve, both completely on paper and without resorting to a computer. "The ground-breaking aspect of these solutions is that they are valid for any law of reflection, which means they can be used in very general ways. The defining moment came for me when I compared these pen-and-paper calculations to what other researchers had done using computer calculations. I was blown away by how well they matched," said Heng.

Successful analysis of the phase curve of Jupiter

"What excites me is not just the discovery of new theory, but also its major implications for interpreting data," says Heng. For example, the Cassini spacecraft measured phase curves of Jupiter in the early 2000s, but an in-depth analysis of the data had not previously been done, probably because the calculations were too computationally expensive. With this new family of solutions, Heng was able to analyse the Cassini phase curves and infer that the atmosphere of Jupiter is filled with clouds made up of large, irregular particles of different sizes. This parallel study has just been published by the *Astrophysical Journal Letters,* in collaboration with Cassini data expert and planetary scientist Liming Li of Houston University in Texas, U.S.A.

New possibilities for the analysis of data from space telescopes

"The ability to write down mathematical solutions for phase curves of reflected light on paper means that one can use them to analyse data in seconds," said Heng. It opens up new ways of interpreting data that were previously infeasible. Heng is collaborating with Pierre Auclair-Desrotour (formerly CSH, currently at

Paris Observatory) to further generalize these mathematical solutions. "Pierre Auclair-Desrotour is a more talented applied mathematician than I am, and we promise exciting results in the near future," said Heng. In the *Nature Astronomy* paper, Heng and his co-authors demonstrated a novel way of analysing the phase curve of the exoplanet Kepler-7b from the Kepler space telescope. Brett Morris led the data analysis part of the paper. "Brett Morris leads the data analysis for the CHEOPS mission in my research group, and his modern data science approach was critical for successfully applying the mathematical solutions to real data," explained Heng. They are currently collaborating with scientists from the American-led TESS space telescope to analyse TESS phase curve data. Heng envisions that these new solutions will lead to novel ways of analysing phase curve data from the upcoming, 10-billion-dollar James Webb Space Telescope, which is due to launch later in 2021. "What excites me most of all is that these mathematical solutions will remain valid long after I am gone, and will probably make their way into standard textbooks," said Heng.

- How disorderly young galaxies grow up and mature

Date: August 27, 2021
Source: Lund University

Using a supercomputer simulation, a research team at Lund University in Sweden has succeeded in following the development of a galaxy over a span of 13.8 billion years. The study shows how, due to interstellar frontal collisions, young and chaotic galaxies over time mature into spiral galaxies such as the Milky Way.

Soon after the Big Bang 13.8 billion years ago, the Universe was an unruly place. Galaxies constantly collided. Stars formed at an enormous rate inside gigantic gas clouds. However, after a few billion years of intergalactic chaos, the unruly, embryonic galaxies became more stable and over time matured into well-ordered spiral galaxies. The exact course of these developments has long been a mystery to the world's astronomers. However, in a new study published in *Monthly Notices of the Royal Astronomical Society,* researchers have been able to provide some clarity on the matter.

"Using a supercomputer, we have created a high-resolution simulation that provides a detailed picture of a galaxy's development since the Big Bang, and how young chaotic galaxies transition into well-ordered spirals" says Oscar Agertz, astronomy researcher at Lund University.

In the study, the astronomers, led by Oscar Agertz and Florent Renaud, use the Milky Way's stars as a starting point. The stars act as time capsules that divulge secrets about distant epochs and the environment in which they were formed. Their positions, speeds and amounts of various chemical elements can therefore, with the assistance of computer simulations, help us understand how our own galaxy was formed.

"We have discovered that when two large galaxies collide, a new disc can be created around the old one due to the enormous inflows of star-forming gas. Our simulation shows that the old and new discs slowly merged over a period of several billion years. This is something that not only resulted in a stable spiral galaxy, but also in populations of stars that are similar to those in the Milky Way," says Florent Renaud, astronomy researcher at Lund University.

The new findings will help astronomers to interpret current and future mappings of the Milky Way. The study points to a new direction for research in which the main focus will be on the interaction between large galaxy collisions and how spiral galaxies' discs are formed. The research team in Lund has already started new super computer simulations in cooperation with the research infrastructure PRACE (Partnership for Advanced Computing in Europe).

"With the current study and our new computer simulations we will generate a lot of information which means we can better understand the Milky Way's fascinating life since the beginning of the Universe," concludes Oscar Agertz.

- Unravelling the mystery of brown dwarfs

Date: August 27, 2021
Source: Université de Genève

Brown dwarfs are astronomical objects with masses between those of planets and stars. The question of where exactly the limits of their mass lie remains a matter of debate, especially since their constitution is very similar to that of low-mass stars. So how do we know whether we are dealing with a brown dwarf or a very low mass star? An international team, led by scientists from the University of

Geneva (UNIGE) and the Swiss National Centre of Competence in Research (NCCR) PlanetS, in collaboration with the University of Bern, has identified five objects that have masses near the border separating stars and brown dwarfs that could help scientists understand the nature of these mysterious objects. The results can be found in the journal *Astronomy & Astrophysics*.

Like Jupiter and other giant gas planets, stars are mainly made of hydrogen and helium. But unlike gas planets, stars are so massive and their gravitational force so powerful that hydrogen atoms fuse to produce helium, releasing huge amounts of energy and light.

'Failed stars'

Brown dwarfs, on the other hand, are not massive enough to fuse hydrogen and therefore cannot produce the enormous amount of light and heat of stars. Instead, they fuse relatively small stores of a heavier atomic version of hydrogen: deuterium. This process is less efficient and the light from brown dwarfs is much weaker than that from stars. This is why scientists often refer to them as 'failed stars'.

"However, we still do not know exactly where the mass limits of brown dwarfs lie, limits that allow them to be distinguished from low-mass stars that can burn hydrogen for many billions of years, whereas a brown dwarf will have a short burning stage and then a colder life," points out Nolan Grieves, a researcher in the Department of Astronomy at the UNIGE's Faculty of Science, a member of the NCCR PlanetS and the study's first author. "These limits vary depending on the chemical composition of the brown dwarf, for example, or the way it formed, as well as its initial radius," he explains. To get a better idea of what these mysterious objects are, we need to study examples in detail. But it turns out that they are rather rare. "So far, we have only accurately characterised about 30 brown dwarfs," says the Geneva-based researcher. Compared to the hundreds of planets that astronomers know in detail, this is very few. All the more so if one considers that their larger size makes brown dwarfs easier to detect than planets.

New pieces to the puzzle

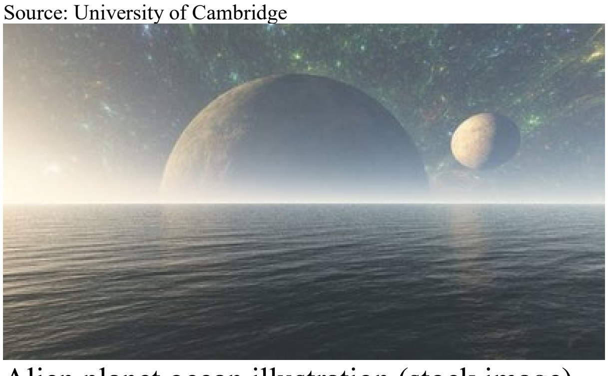
Today, the international team characterized five companions that were originally identified with the Transiting Exoplanet Survey Satellite (TESS) as TESS objects of interest (TOI) -- TOI-148, TOI-587, TOI-681, TOI-746 and TOI-1213. These are called 'companions' because they orbit their respective host stars. They do so with periods of 5 to 27 days, have radii between 0.81 and 1.66 times that of Jupiter and are between 77 and 98 times more massive. This places them on the borderline between brown dwarfs and stars.

These five new objects therefore contain valuable information. "Each new discovery reveals additional clues about the nature of brown dwarfs and gives us a better understanding of how they form and why they are so rare," says Monika Lendl, a researcher in the Department of Astronomy at the UNIGE and a member of the NCCR PlanetS. One of the clues the scientists found to show these objects are brown dwarfs is the relationship between their size and age, as explained by François Bouchy, professor at UNIGE and member of the NCCR PlanetS: "Brown dwarfs are supposed to shrink over time as they burn up their deuterium reserves and cool down. Here we found that the two oldest objects, TOI 148 and 746, have a smaller radius, while the two younger companions have larger radii."

Yet these objects are so close to the limit that they could just as easily be very low-mass stars, and astronomers are still unsure whether they are brown dwarfs. "Even with these additional objects, we still lack the numbers to draw definitive conclusions about the differences between brown dwarfs and low-mass stars. Further studies are needed to find out more," concludes Grieves.

- New class of habitable exoplanets represent a big step forward in the search for life

Date: August 25, 2021
Source: University of Cambridge



Alien planet ocean illustration (stock image).
Credit: © Ryan Rad / stock.adobe.com

A new class of exoplanet very different to our own, but which could support life, has been identified by astronomers, which could greatly accelerate the search for life outside our Solar System.

In the search for life elsewhere, astronomers have mostly looked for planets of a similar size, mass, temperature and atmospheric composition to Earth. However, astronomers from the University of Cambridge believe there are more promising possibilities out there.
The researchers have identified a new class of habitable planets, dubbed 'Hycean' planets -- hot, ocean-covered planets with hydrogen-rich atmospheres -- which are more numerous and observable than Earth-like planets.
The researchers say the results, reported in *The Astrophysical Journal*, could mean that finding biosignatures of life outside our Solar System within the next two or three years is a real possibility.
"Hycean planets open a whole new avenue in our search for life elsewhere," said Dr Nikku Madhusudhan from Cambridge's Institute of Astronomy, who led the research.
Many of the prime Hycean candidates identified by the researchers are bigger and hotter than Earth, but still have the characteristics to host large oceans that could support microbial life similar to that found in some of Earth's most extreme aquatic environments.
These planets also allow for a far wider habitable zone, or 'Goldilocks zone', compared to Earth-like planets. This means that they could still support life even though they lie outside the range where a planet similar to Earth would need to be in order to be habitable.
Thousands of planets outside our Solar System have been discovered since the first exoplanet was identified nearly 30 years ago. The vast majority are planets between the sizes of Earth and Neptune and are often referred to as 'super-Earths' or 'mini-Neptunes': they can be predominantly rocky or ice giants with hydrogen-rich atmospheres, or something in between.
Most mini-Neptunes are over 1.6 times the size of Earth: smaller than Neptune but too big to have rocky interiors like Earth. Earlier studies of such planets have found that the pressure and temperature beneath their hydrogen-rich atmospheres would be too high to support life.
However, a recent study on the mini-Neptune K2-18b by Madhusudhan's team found that in certain conditions these planets could support life. The result led to a detailed investigation into the full range of planetary and stellar properties for which these conditions are possible, which known exoplanets may satisfy those conditions, and whether their biosignatures may be observable.
The investigation led the researchers to identify a new class of planets, Hycean planets, with massive planet-wide oceans beneath hydrogen-rich atmospheres. Hycean planets can be up to 2.6 times larger than Earth and have atmospheric temperatures up to nearly 200 degrees Celsius, but their oceanic conditions could be similar to those conducive for microbial life in Earth's oceans. Such planets also include tidally locked 'dark' Hycean worlds that may have habitable conditions only on their permanent night sides, and 'cold' Hycean worlds that receive little radiation from their stars.
Planets of this size dominate the known exoplanet population, although they have not been studied in nearly as much detail as super-Earths. Hycean worlds are likely quite common, meaning that the most promising places to look for life elsewhere in the Galaxy may have been hiding in plain sight.
However, size alone is not enough to confirm whether a planet is Hycean: other aspects such as mass, temperature and atmospheric properties are required for confirmation.
When trying to determine what the conditions are like on a planet many light years away, astronomers first need to determine whether the planet lies in the habitable zone of its star, and then look for molecular signatures to infer the planet's atmospheric and internal structure, which govern the surface conditions, presence of oceans and potential for life.
Astronomers also look for certain biosignatures which could indicate the possibility of life. Most often, these are oxygen, ozone, methane and nitrous oxide, which are all present on Earth. There are also a number of other biomarkers, such as methyl chloride and dimethyl sulphide, that are less abundant on Earth but can be promising indicators of life on planets with hydrogen-rich atmospheres where oxygen or ozone may not be as abundant.
"Essentially, when we've been looking for these various molecular signatures, we have been focusing on planets similar to Earth, which is a reasonable place to start," said Madhusudhan. "But we think Hycean planets offer a better chance of finding several trace biosignatures."

"It's exciting that habitable conditions could exist on planets so different from Earth," said co-author Anjali Piette, also from Cambridge.
Madhusudhan and his team found that a number of trace terrestrial biomarkers expected to be present in Hycean atmospheres would be readily detectable with spectroscopic observations in the near future. The larger sizes, higher temperatures and hydrogen-rich atmospheres of Hycean planets make their atmospheric signatures much more detectable than Earth-like planets.
The Cambridge team identified a sizeable sample of potential Hycean worlds which are prime candidates for detailed study with next-generation telescopes, such as the James Webb Space Telescope (JWST), which is due to be launched later this year. These planets all orbit red dwarf stars between 35-150 light years away: close by astronomical standards. Planned JWST observations of the most promising candidate, K2-18b, could lead to the detection of one or more biosignature molecules.
"A biosignature detection would transform our understanding of life in the universe," said Madhusudhan. "We need to be open about where we expect to find life and what form that life could take, as nature continues to surprise us in often unimaginable ways."

- ❖ Space scientists reveal secret behind Jupiter's 'energy crisis'

Date: August 4, 2021
Source: University of Leicester

Planet Jupiter (stock image; elements furnished by NASA).
Credit: © Vadimsadovski / stock.adobe.com

New research published in *Nature* has revealed the solution to Jupiter's 'energy crisis', which has puzzled astronomers for decades.
Space scientists at the University of Leicester worked with colleagues from the Japanese Space Agency (JAXA), Boston University, NASA's Goddard Space Flight Centre and the National Institute of Information and Communications Technology (NICT) to reveal the mechanism behind Jupiter's atmospheric heating.
Now, using data from the Keck Observatory in Hawai'i, astronomers have created the most-detailed yet global map of the gas giant's upper atmosphere, confirming for the first time that Jupiter's powerful aurorae are responsible for delivering planet-wide heating.
Dr James O'Donoghue is a researcher at JAXA and completed his PhD at Leicester, and is lead author for the research paper. He said:
"We first began trying to create a global heat map of Jupiter's uppermost atmosphere at the University of Leicester. The signal was not bright enough to reveal anything outside of Jupiter's polar regions at the time, but with the lessons learned from that work we managed to secure time on one of the largest, most competitive telescopes on Earth some years later.
"Using the Keck telescope we produced temperature maps of extraordinary detail. We found that temperatures start very high within the aurora, as expected from previous work, but now we could observe that Jupiter's aurora, despite taking up less than 10% of the area of the planet, appear to be heating the whole thing.
"This research started in Leicester and carried on at Boston University and NASA before ending at JAXA in Japan. Collaborators from each continent working together made this study successful, combined with data from NASA's Juno spacecraft in orbit around Jupiter and JAXA's Hisaki spacecraft, an observatory in space."
Dr Tom Stallard and Dr Henrik Melin are both part of the School of Physics and Astronomy at the University of Leicester. Dr Stallard added:
"There has been a very long-standing puzzle in the thin atmosphere at the top of every Giant Planet within our solar system. With every Jupiter space mission, along with ground-based observations, over the past 50 years, we have consistently measured the equatorial temperatures as being much too hot.
"This 'energy crisis' has been a long standing issue -- do the models fail to properly model how heat flows from the aurora, or is there some other unknown heat source near the equator?
"This paper describes how we have mapped this region in unprecedented detail and have

shown that, at Jupiter, the equatorial heating is directly associated with auroral heating."
Aurorae occur when charged particles are caught in a planet's magnetic field. These spiral along the field lines towards the planet's magnetic poles, striking atoms and molecules in the atmosphere to release light and energy. On Earth, this leads to the characteristic light show that forms the Aurora Borealis and Australis. At Jupiter, the material spewing from its volcanic moon, Io, leads to the most powerful aurora in the Solar System and enormous heating in the polar regions of the planet.
Although the Jovian aurorae have long been a prime candidate for heating the planet's atmosphere, observations have previously been unable to confirm or deny this until now.
Previous maps of the upper atmospheric temperature were formed using images consisting of only several pixels. This is not enough resolution to see how the temperature might be changed across the planet, providing few clues as to the origin of the extra heat.
Researchers created five maps of the atmospheric temperature at different spatial resolutions, with the highest resolution map showing an average temperature measurement for squares two degrees longitude 'high' by two degrees latitude 'wide'.
The team scoured more than 10,000 individual data points, only mapping points with an uncertainty of less than five per cent.
Models of the atmospheres of gas giants suggest that they work like a giant refrigerator, with heat energy drawn from the equator towards the pole, and deposited in the lower atmosphere in these pole regions.
These new findings suggest that fast-changing aurorae may drive waves of energy against this poleward flow, allowing heat to reach the equator.
Observations also showed a region of localised heating in the sub-auroral region that could be interpreted as a limited wave of heat propagating equatorward, which could be interpreted as evidence of the process driving heat transfer.
Planetary research at the University of Leicester spans the breadth of Jovian system, from the planet's magnetosphere and atmosphere, out to its diverse collection of satellites.
Leicester researchers are members of the Juno mission made up of a global team of astronomers observing the giant planet, and are leading Jupiter observations from the forthcoming James Webb Space Telescope. Leicester also plays a leading role in science and instrumentation on the European Space Agency (ESA)'s Jupiter Icy Moons Explorer (JUICE), due for launch in 2022.

- ❖ Will it be safe for humans to fly to Mars?

Mission would be viable if it doesn’t exceed four years, international research team concludes
Date: August 26, 2021
Source: University of California - Los Angeles

Spaceship on Mars illustration (stock image).
Credit: © dottedyeti / stock.adobe.com
Sending human travellers to Mars would require scientists and engineers to overcome a range of technological and safety obstacles. One of them is the grave risk posed by particle radiation from the sun, distant stars and galaxies.
Answering two key questions would go a long way toward overcoming that hurdle: Would particle radiation pose too grave a threat to human life throughout a round trip to the red planet? And, could the very timing of a mission to Mars help shield astronauts and the spacecraft from the radiation?
In a new article published in the peer-reviewed journal *Space Weather*, an international team of space scientists, including researchers from UCLA, answers those two questions with a "no" and a "yes."
That is, humans should be able to safely travel to and from Mars, provided that the spacecraft has sufficient shielding and the round trip is shorter than approximately four years. And the timing of a human mission to Mars would indeed make a difference: The scientists determined that the best time for a flight to leave Earth would be when solar activity is at its peak, known as the solar maximum.
The scientists' calculations demonstrate that it would be possible to shield a Mars-bound spacecraft from energetic particles from the sun because, during solar maximum, the most dangerous and energetic particles from distant

galaxies are deflected by the enhanced solar activity.
A trip of that length would be conceivable. The average flight to Mars takes about nine months, so depending on the timing of launch and available fuel, it is plausible that a human mission could reach the planet and return to Earth in less than two years, according to Yuri Shprits, a UCLA research geophysicist and co-author of the paper.
"This study shows that while space radiation imposes strict limitations on how heavy the spacecraft can be and the time of launch, and it presents technological difficulties for human missions to Mars, such a mission is viable," said Shprits, who also is head of space physics and space weather at GFZ Research Centre for Geosciences in Potsdam, Germany.
The researchers recommend a mission not longer than four years because a longer journey would expose astronauts to a dangerously high amount of radiation during the round trip -- even assuming they went when it was relatively safer than at other times. They also report that the main danger to such a flight would be particles from outside of our solar system.
Shprits and colleagues from UCLA, MIT, Moscow's Skolkovo Institute of Science and Technology and GFZ Potsdam combined geophysical models of particle radiation for a solar cycle with models for how radiation would affect both human passengers -- including its varying effects on different bodily organs -- and a spacecraft. The modelling determined that having a spacecraft's shell built out of a relatively thick material could help protect astronauts from radiation, but that if the shielding is too thick, it could actually increase the amount of secondary radiation to which they are exposed.
The two main types of hazardous radiation in space are solar energetic particles and galactic cosmic rays; the intensity of each depends on solar activity. Galactic cosmic ray activity is lowest within the six to 12 months after the peak of solar activity, while solar energetic particles' intensity is greatest during solar maximum, Shprits said.

- Stellar collision triggers supernova explosion

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Source: National Radio Astronomy Observatory

Astronomers have found dramatic evidence that a black hole or neutron star spiralled its way into the core of a companion star and caused that companion to explode as a supernova. The astronomers were tipped off by data from the Very Large Array Sky Survey (VLASS), a multi-year project using the National Science Foundation's Karl G. Jansky Very Large Array (VLA).
"Theorists had predicted that this could happen, but this is the first time we've actually seen such an event," said Dillon Dong, a graduate student at Caltech and lead author on a paper reporting the discovery in the journal *Science*.
The first clue came when the scientists examined images from VLASS, which began observations in 2017, and found an object brightly emitting radio waves but which had not appeared in an earlier VLA sky survey, called Faint Images of the Radio Sky at Twenty centimetres (FIRST). They made subsequent observations of the object, designated VT 1210+4956, using the VLA and the Keck telescope in Hawaii. They determined that the bright radio emission was coming from the outskirts of a dwarf, star-forming galaxy some 480 million light-years from Earth. They later found that an instrument aboard the International Space Station had detected a burst of X-rays coming from the object in 2014.
The data from all these observations allowed the astronomers to piece together the fascinating history of a centuries-long death dance between two massive stars. Like most stars that are much more massive than our Sun, these two were born as a binary pair, closely orbiting each other. One of them was more massive than the other and evolved through its normal, nuclear fusion-powered lifetime more quickly and exploded as a supernova, leaving behind either a black hole or a super dense neutron star.
The black hole or neutron star's orbit grew steadily closer to its companion, and about 300 years ago it entered the companion's atmosphere, starting the death dance. At this point, the interaction began spraying gas away from the companion into space. The ejected gas, spiralling outward, formed an expanding, donut-shaped ring, called a torus, around the pair.
Eventually, the black hole or neutron star made its way inward to the companion star's core, disrupting the nuclear fusion producing the energy that kept the core from collapsing of its own gravity. As the core collapsed, it briefly formed a disk of material closely

orbiting the intruder and propelled a jet of material outward from the disk at speeds approaching that of light, drilling its way through the star.

"That jet is what produced the X-rays seen by the MAXI instrument aboard the International Space Station, and this confirms the date of this event in 2014," Dong said.

The collapse of the star's core caused it to explode as a supernova, following its sibling's earlier explosion.

"The companion star was going to explode eventually, but this merger accelerated the process," Dong said.

The material ejected by the 2014 supernova explosion moved much faster than the material thrown off earlier from the companion star, and by the time VLASS observed the object, the supernova blast was colliding with that material, causing powerful shocks that produced the bright radio emission seen by the VLA.

"All the pieces of this puzzle fit together to tell this amazing story," said Gregg Hallinan of Caltech. "The remnant of a star that exploded a long time ago plunged into its companion, causing it, too, to explode," he added.

The key to the discovery, Hallinan said, was VLASS, which is imaging the entire sky visible at the VLA's latitude -- about 80 percent of the sky -- three times over seven years. One of the objectives of doing VLASS that way is to discover transient objects, such as supernova explosions, that emit brightly at radio wavelengths. This supernova, caused by a stellar merger, however, was a surprise.

"Of all the things we thought we would discover with VLASS, this was not one of them," Hallinan said.

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