South Downs Mercury

The monthly circular of South Downs Astronomical Society
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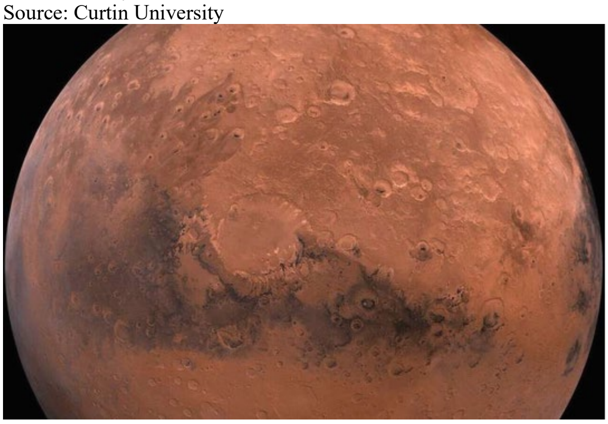
Main Speaker 19:30 Main Talk Niel Phillipson The Atacama Large Millimetre/Sub-Millimetre Array
The meeting will be accessible via Zoom

A reminder to member who have not yet renewed subscriptions were due in December

- Shocked zircon find a 'one-off gift' from Mars

Date: February 2, 2022
Source: Curtin University



Credit: Pixabay/CC0 Public Domain

Curtin University researchers studying a Martian meteorite have found the first evidence of high-intensity damage caused by asteroid impact, in findings that have implications for understanding when conditions suitable for life may have existed on early Mars.

Published in leading journal *Science Advances*, the research examined grains of the mineral zircon in Martian meteorite NWA 7034. The meteorite, colloquially known as 'Black Beauty', is a rare sample of the surface of Mars. The original 320-gram rock was found in northern Africa and first reported in 2013.

Lead author Morgan Cox, a PhD candidate from Curtin's Space Science and Technology Centre (SSTC) in the School of Earth and Planetary Sciences, described the meteorite as a collection of broken rock fragments and minerals, mostly basalt, that solidified and became a rock over time. A zircon found inside the meteorite preserves evidence of damage that only occurs during large meteorite impacts.

"This grain is truly a one-off gift from the Red Planet. High-pressure shock deformation has not previously been found in any minerals from Black Beauty. This discovery of shock damage in a 4.45 billion-year-old Martian zircon provides new evidence of dynamic processes that affected the surface of early Mars," Ms Cox said.

"The type of shock damage in the Martian zircon involves 'twinning', and has been reported from all of the biggest impact sites on Earth, including the one in Mexico that killed off the dinosaurs, as well as the Moon, but not previously from Mars."

Co-author Dr Aaron Cavosie, also from Curtin's SSTC, said the occurrence of zircon grains in the Black Beauty meteorite provided physical evidence of large impacts on early Mars, and had implications for the habitability of the young planet.

"Prior studies of zircon in Martian meteorites proposed that conditions suitable for life may have existed by 4.2 billion years ago based on the absence of definitive shock damage" Dr Cavosie said.

"Mars remained subject to impact bombardment after this time, on the scale known to cause mass extinctions on Earth. The zircon we describe provides evidence of such impacts, and highlights the possibility that the habitability window may have occurred later than previously thought, perhaps coinciding with evidence for liquid water on Mars by 3.9 to 3.7 billion years ago."

The research team also included collaborators from The University of Western Australia and the University of Glasgow.

- Planetary bodies observed for first time in 'habitable zone' of dead star

Date: February 11, 2022

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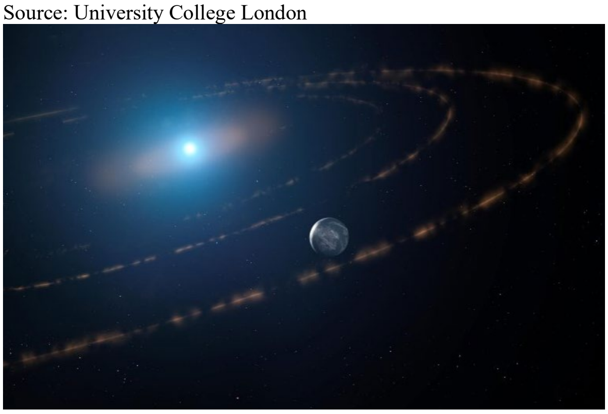
Source: University College London



An artist's impression of the white dwarf star WD1054–226 orbited by clouds of planetary debris and a major planet in the habitable zone. Credit: Mark A. Garlick / markgarlick.com

A ring of planetary debris studded with moon-sized structures has been observed orbiting close to a white dwarf star, hinting at a nearby planet in the "habitable zone" where water and life could exist, according to a new study led by UCL researchers.

White dwarfs are glowing embers of stars that have burned through all their hydrogen fuel. Nearly all stars, including the Sun, will eventually become white dwarfs, but very little is known about their planetary systems.

In the study, published in *Monthly Notices of the Royal Astronomical Society*, an international team of researchers measured light from a white dwarf in the Milky Way known as WD1054-226, using data from ground- and space-based telescopes.

To their surprise, they found pronounced dips in light corresponding to 65 evenly spaced clouds of planetary debris orbiting the star every 25 hours. The researchers concluded that the precise regularity of the transiting structures -- dimming the star's light every 23 minutes -- suggests they are kept in such a precise arrangement by a nearby planet.

Lead author Professor Jay Farihi (UCL Physics & Astronomy) said: "This is the first time astronomers have detected any kind of planetary body in the habitable zone of a white dwarf.

"The moon-sized structures we have observed are irregular and dusty (e.g. comet-like) rather than solid, spherical bodies. Their absolute regularity, one passing in front of the star every 23 minutes, is a mystery we cannot currently explain.

"An exciting possibility is that these bodies are kept in such an evenly-spaced orbital pattern because of the gravitational influence of a nearby planet. Without this influence, friction and collisions would cause the structures to disperse, losing the precise regularity that is observed. A precedent for this 'shepherding' is the way the gravitational pull of moons around Neptune and Saturn help to create stable ring structures orbiting these planets.

"The possibility of a planet in the habitable zone is exciting and also unexpected; we were not looking for this. However, it is important to keep in mind that more evidence is necessary to confirm the presence of a planet. We cannot observe the planet directly so confirmation may come by comparing computer models with further observations of the star and orbiting debris."

It is expected that this orbit around the white dwarf was swept clear during the giant star phase of its life, and thus any planet that can potentially host water and thus life would be a recent development. The area would be habitable for at least two billion years, including at least one billion years into the future.

More than 95% of all stars will eventually become white dwarfs. The exceptions are the largest stars that explode and become either black holes or neutron stars.

Professor Farihi added: "Since our Sun will become a white dwarf in a few billion years, our study provides a glimpse into the future of our own solar system."

When stars begin running out of hydrogen, they expand and cool, becoming red giants. The Sun will enter this phase in four to five billion years, swallowing Mercury, Venus, and possibly Earth. Once the outer material has gently blown away and hydrogen is exhausted, the hot core of the star remains, slowly cooling over billions of years -- this is the star's white dwarf phase.

Planets orbiting white dwarfs are challenging for astronomers to detect because the stars are much fainter than main-sequence stars (like the Sun). So far, astronomers have only found tentative evidence of a gas giant (like Jupiter) orbiting a white dwarf.

For the new study, researchers observed WD1054-226, a white dwarf 117 light years away, recording changes in its light over 18 nights using the ULTRACAM high-speed camera fixed on to the ESO 3.5m New Technology Telescope (NTT) at the La Silla Observatory in Chile. In order to better interpret the changes in light, the researchers also looked at data from the NASA Transiting Exoplanet Survey Satellite (TESS), which allowed the researchers to confirm the planetary structures had a 25-hour orbit.

They found that the light from WD1054-226 was always somewhat obscured by enormous clouds of orbiting material passing in front of it, suggesting a ring of planetary debris orbiting the star.
The habitable zone, sometimes called the Goldilocks zone, is the area where the temperature would theoretically allow liquid water to exist on the surface of a planet. Compared to a star like the Sun, the habitable zone of a white dwarf will be smaller and closer to the star as white dwarfs give off less light and thus heat.
The structures observed in the study orbit in an area that would have been enveloped by the star while it was a red giant, so are likely to have formed or arrived relatively recently, rather than survived from the birth of the star and its planetary system.
The study received funding from the UK's Science and Technology Facilities Council (STFC) and involved a team of researchers from six countries, including Boston University, the University of Warwick, Lund University, the University of Cambridge, the University of St Andrews, Wesleyan University, the University of La Laguna, Naresuan University, the University of Sheffield, and the Instituto de Astrofísica de Canarias.

- New planet detected around Proxima Centauri, closest star our solar system

Date: February 10, 2022
Source: ESO

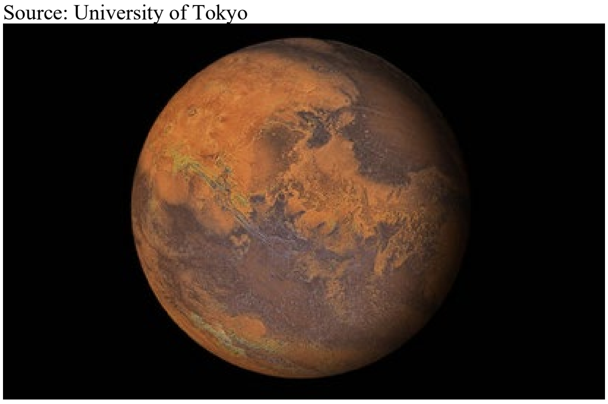

Illustration of exoplanet orbiting star (stock image).
Credit: © dottedyeti / stock.adobe.com

A team of astronomers using the European Southern Observatory's Very Large Telescope (ESO's VLT) in Chile have found evidence of another planet orbiting Proxima Centauri, the closest star to our Solar System. This candidate planet is the third detected in the system and the lightest yet discovered orbiting this star. At just a quarter of Earth's mass, the planet is also one of the lightest exoplanets ever found.
"The discovery shows that our closest stellar neighbour seems to be packed with interesting new worlds, within reach of further study and future exploration," explains João Faria, a researcher at the Instituto de Astrofísica e Ciências do Espaço, Portugal and lead author of the study published today in *Astronomy & Astrophysics*. Proxima Centauri is the closest star to the Sun, lying just over four light-years away.
The newly discovered planet, named Proxima d, orbits Proxima Centauri at a distance of about four million kilometres, less than a tenth of Mercury's distance from the Sun. It orbits between the star and the habitable zone -- the area around a star where liquid water can exist at the surface of a planet -- and takes just five days to complete one orbit around Proxima Centauri.
The star is already known to host two other planets: Proxima b, a planet with a mass comparable to that of Earth that orbits the star every 11 days and is within the habitable zone, and candidate Proxima c, which is on a longer five-year orbit around the star.
Proxima b was discovered a few years ago using the HARPS instrument on ESO's 3.6-metre telescope. The discovery was confirmed in 2020 when scientists observed the Proxima system with a new instrument on ESO's VLT that had greater precision, the Echelle SPectrograph for Rocky Exoplanets and Stable Spectroscopic Observations (ESPRESSO). It was during these more recent VLT observations that astronomers spotted the first hints of a signal corresponding to an object with a five-day orbit. As the signal was so weak, the team had to conduct follow-up observations with ESPRESSO to confirm that it was due to a planet, and not simply a result of changes in the star itself.
"After obtaining new observations, we were able to confirm this signal as a new planet candidate," Faria says. "I was excited by the challenge of detecting such a small signal and, by doing so, discovering an exoplanet so close to Earth."
At just a quarter of the mass of Earth, Proxima d is the lightest exoplanet ever measured using the radial velocity technique, surpassing a planet recently discovered in the L 98-59 planetary system. The technique works by picking up tiny wobbles in the motion of a star created by an orbiting planet's gravitational pull. The effect of Proxima d's gravity is so small that it only causes Proxima Centauri to move back and forth at around 40 centimetres per second (1.44 kilometres per hour).

"This achievement is extremely important," says Pedro Figueira, ESPRESSO instrument scientist at ESO in Chile. "It shows that the radial velocity technique has the potential to unveil a population of light planets, like our own, that are expected to be the most abundant in our galaxy and that can potentially host life as we know it."
"This result clearly shows what ESPRESSO is capable of and makes me wonder about what it will be able to find in the future," Faria adds.
ESPRESSO's search for other worlds will be complemented by ESO's Extremely Large Telescope (ELT), currently under construction in the Atacama Desert, which will be crucial to discovering and studying many more planets around nearby stars.

- How Mars lost its oceans

Experiments to simulate Mars’ core may explain the loss of its magnetic field
Date: February 8, 2022
Source: University of Tokyo



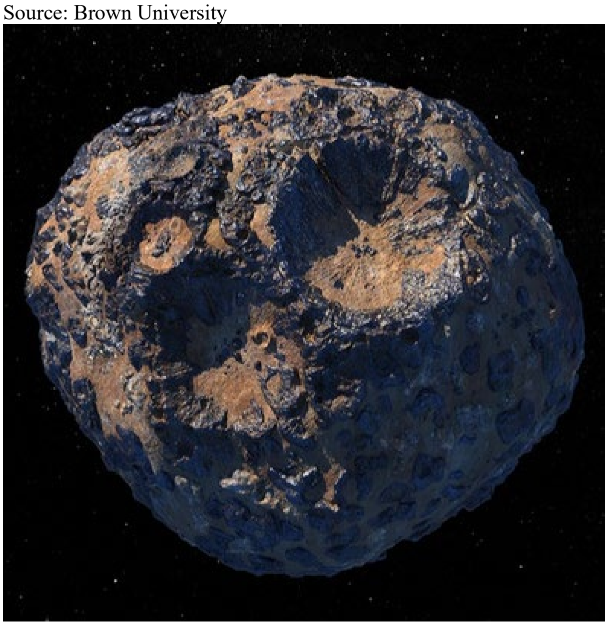
Planet Mars illustration (stock image; elements furnished by NASA).
Credit: © Stockbym / stock.adobe.com

It has long been known that Mars once had oceans due in part to a protective magnetic field similar to Earth's. However, the magnetic field disappeared, and new research may finally be able to explain why. Researchers recreated conditions expected in the core of Mars billions of years ago and found that the behaviour of the molten metal thought to be present likely gave rise to a brief magnetic field that was destined to fade away.
Whether it's due to science fiction or the fact that you can see it with your own eyes from Earth, Mars has captured the imagination of people for centuries. It's one of the closest planets to us and has been studied with all manner of scientific instruments aboard the various unmanned space probes that have explored it and continue to do so. Yet, despite this, there are some big unanswered questions about Mars -- the answers to which could even shed light on our own distant past and future, given that Earth, Mars and all our neighbouring planets were born of the same cosmic stuff.
Some big questions about Mars have already been answered. For example, we know that many visible features of Mars are proof it used to have oceans and a protective magnetic field. But one question in particular had been on the mind of Professor Kei Hirose from the University of Tokyo's Department of Earth and Planetary Science: There must have been a magnetic field around Mars, so why was it there at all, and why was it there so briefly?
Compelled to answer this question, a team led by Ph.D. student Shunpei Yokoo in the Hirose lab explored a novel way to test something so distant from us in both time and space.
"Earth's magnetic field is driven by inconceivably huge convection currents of molten metals in its core. Magnetic fields on other planets are thought to work the same way," said Hirose. "Though the internal composition of Mars is not yet known, evidence from meteorites suggests it is molten iron enriched with sulphur. Furthermore, seismic readings from NASA's InSight probe on the surface tell us Mars' core is larger and less dense than previously thought. These things imply the presence of additional lighter elements such as hydrogen. With this detail, we prepare iron alloys that we expect constitute the core and subject them to experiments."
The experiment involved diamonds, lasers, and an unexpected surprise. Yokoo made a sample of material containing iron, sulphur and hydrogen, Fe-S-H, which is what he and his team expect the core of Mars was once made from. They placed this sample between two diamonds and compressed it while heating it with an infrared laser. This was to simulate the estimated temperature and pressure at the core. Sample observations with X-ray and electron beams allowed the team to image what was going on during melting under pressure, and even map how the composition of the sample changed during that time.
"We were very surprised to see a particular behaviour that could explain a lot. The initially homogeneous Fe-S-H separated out into two distinct liquids with a level of complexity that has not been seen before under these kinds of pressures," said Hirose. "One of the iron liquids was rich in sulphur, the other rich in hydrogen, and this is key to

explaining the birth and eventually death of the magnetic field around Mars."
The liquid iron rich in hydrogen and poor in sulphur, being less dense, would have risen above the denser sulphur-rich, hydrogen-poor liquid iron, causing convection currents. These currents, similar to those on Earth, would have driven a magnetic field capable of maintaining hydrogen in an atmosphere around Mars, which in turn would have allowed water to exist as a liquid. However, it was not to last. Unlike the Earth's internal convection currents which are extremely long lasting, once the two liquids had fully separated, there would have been no more currents to drive a magnetic field. And when that happened, hydrogen in the atmosphere was blown out to space by solar wind, leading to the breakdown of water vapor and eventually the evaporation of the Martian oceans. And this would all have taken place about 4 billion years ago.
"With our results in mind, further seismic study of Mars will hopefully verify the core is indeed in distinct layers as we predict," said Hirose. "If that is the case, it would help us complete the story of how the rocky planets, including Earth, formed, and explain their composition. And you might be thinking that the Earth could one day lose its magnetic field as well, but don't worry, that won't happen for at least a billion years."
This work was supported by the Japan Society for the Promotion of Science (JSPS) KAKENHI (Grant No. 16H06285 and 21H04506).

- Psyche, the iron giant of asteroids, may be less iron than researchers thought

Date: February 15, 2022
Source: Brown University



The asteroid 16 Psyche, which NASA intends to visit with a spacecraft in 2026, may be less heavy metal and more hard rock than scientists have surmised, according to a new study by researchers from Brown and Purdue universities.
Psyche, which orbits the sun in the asteroid belt between Mars and Jupiter, is the largest of the M-type asteroids, which are composed chiefly of iron and nickel as opposed to the silicate rocks that make up most other asteroids. But when viewed from Earth, Psyche sends mixed signals about its composition.
The light it reflects tells scientists that the surface is indeed mostly metal. That has led to conjecture that Psyche may be the exposed iron core of a primordial planetary body -- one whose rocky crust and mantle were blasted away by an ancient collision. However, measurements of Psyche's mass and density tell a different story. The way its gravity tugs on neighbouring bodies suggests that Psyche is far less dense than a giant hunk of iron should be. So if Psyche is indeed all metal, it would have to be highly porous -- a bit like a giant ball of steel wool with nearly equal parts void space and solid metal.
"What we wanted to do with this study was see whether it was possible for an iron body the size of Psyche to maintain that near-50% porosity," said Fiona Nichols-Fleming, a Ph.D. student at Brown and study's lead author. "We found that it's very unlikely."
For the study, published in *Geophysical Research Letters,* Nichols-Fleming worked with Alex Evans, an assistant professor at Brown, and Purdue professors Brandon Johnson and Michael Sori. The team created a computer model, based on known thermal properties of metallic iron, to estimate how the porosity of a large iron body would evolve over time.
The model shows that to remain highly porous, Psyche's internal temperature would have to cool below 800 Kelvin very shortly after its formation. At temperatures above that, iron would have been so malleable that Psyche's own gravity would have collapsed most of the pore space within its bulk. Based on what is known about conditions in the early solar system, the researchers say, it's extremely unlikely that a body of Psyche's size -- about 140 miles in diameter -- could have cooled so quickly.

In addition, any event that may have added porosity to Psyche after its formation -- a massive impact, for example -- would likely have also heated Psyche back up above 800 K. So any newly introduced porosity would have been unlikely to last.
Taken together, the results suggest that Psyche probably isn't a porous, all-iron body, the researchers conclude. More likely, it's harbouring a hidden rocky component that drives its density down. But if Psyche does have a rocky component, why does its surface look so metallic when viewed from Earth? There are few possible explanations, the researchers say.
One of those possibilities is ferro volcanism -- iron-spewing volcanoes. It's possible, the researchers say, that Psyche is actually a differentiated body with a rocky mantle and an iron core. But widespread ferro volcanic activity may have brought large amounts of Psyche's core up to the surface, putting an iron coating atop its rocky mantle. Prior research by Johnson and Evans has shown that ferro volcanism is possible on a body like Psyche.
Whatever the case, scientists will soon get a much clearer picture of this mysterious asteroid. Later this year, NASA plans to launch a spacecraft that will rendezvous with Psyche after a four-year journey to the asteroid belt.
"The mission is exciting because Psyche is such a bizarre and mysterious thing," Nichols-Fleming said. "So anything the mission finds will be really important new data points for the solar system."

- How galaxies can exist without dark matter

In simulations, collisions cause smaller star groupings to lose material
Date: February 14, 2022
Source: University of California – Irvine

Galaxy illustration (stock image).
Credit: © alphaspirit / stock.adobe.com

In a new *Nature Astronomy* study, an international team led by astrophysicists from the University of California, Irvine and Pomona College report how, when tiny galaxies collide with bigger ones, the bigger galaxies can strip the smaller galaxies of their dark matter -- matter that we can't see directly, but which astrophysicists think must exist because, without its gravitational effects, they couldn't explain things like the motions of a galaxy's stars.
It's a mechanism that has the potential to explain how galaxies might be able to exist without dark matter -- something once thought impossible.
It started in 2018 when astrophysicists Shany Danieli and Pieter van Dokkum of Princeton University and Yale University observed two galaxies that seemed to exist without most of their dark matter.
"We were expecting large fractions of dark matter," said Danieli, who's a co-author on the latest study. "It was quite surprising, and a lot of luck, honestly."
The lucky find, which van Dokkum and Danieli reported on in a *Nature* paper in 2018 and in an *Astrophysical Journal Letters* paper in 2020, threw the galaxies-need-dark-matter paradigm into turmoil, potentially upending what astrophysicists had come to see as a standard model for how galaxies work.
"It's been established for the last 40 years that galaxies have dark matter," said Jorge Moreno, an astronomy professor at Pomona College, who's the lead author of the new paper. "In particular, low-mass galaxies tend to have significantly higher dark matter fractions, making Danieli's finding quite surprising. For many of us, this meant that our current understanding of how dark matter helps galaxies grow needed an urgent revision."
The team ran computer models that simulated the evolution of a chunk of the universe -- one about 60 million light years across -- starting soon after the Big Bang and running all the way to the present.
The team found seven galaxies devoid of dark matter. After several collisions with neighbouring galaxies 1,000-times more massive, they were stripped of most of their material, leaving behind nothing but stars and some residual dark matter.
"It was pure serendipity," said Moreno. "The moment I made the first images, I shared them

immediately with Danieli, and invited her to collaborate."

Robert Feldmann, a professor at the University of Zurich who designed the new simulation, said that "this theoretical work shows that dark matter-deficient galaxies should be very common, especially in the vicinity of massive galaxies."

UCI's James Bullock, an astrophysicist who's an expert on low-mass galaxies, described how he and the team didn't build their model just so they could create galaxies without dark matter -- something he said makes the model stronger, because it wasn't designed in any way to create the collisions that they eventually found. "We don't presuppose the interactions," said Bullock.

Confirming that galaxies lacking dark matter can be explained in a universe where there's lots of dark matter is a sigh of relief for researchers like Bullock, whose career and everything he's discovered therein hinges on dark matter being the thing that makes galaxies behave the way they do.

"The observation that there are dark matter-free galaxies has been a little bit worrying to me." said Bullock. "We have a successful model, developed over decades of hard work, where most of the matter in the cosmos is dark. There is always the possibility that nature has been fooling us."

But, Moreno said, "you don't have to get rid of the standard dark matter paradigm."

Now that astrophysicists know how a galaxy might lose its dark matter, Moreno and his collaborators hope the findings inspire researchers who look at the night sky to look for real-world massive galaxies they might be in the process of stripping dark matter away from smaller ones.

"It still doesn't mean this model is right," Bullock said. "A real test will be to see if these things exist with the frequency and general characteristics that match our predictions."

As part of this new work, Moreno, who has indigenous roots, received permission from Cherokee leaders to name the seven dark matter-free galaxies found in their simulations in honour of the seven Cherokee clans: Bird, Blue, Deer, Long Hair, Paint, Wild Potato and Wolf.

"I feel a personal connection to these galaxies," said Moreno, who added that, just as the more massive galaxies robbed the smaller galaxies of their dark matter, "many people of indigenous ancestry were stripped of our culture. But our core remains, and we are still thriving."

Funding for the work came from the National Science Foundation, sabbatical leave support for Moreno from Pomona College and the Harry and Grace Steele Foundation, and, for Danieli, from NASA through Hubble Fellowship grant HST-HF2-51454.001-A awarded by the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Incorporated, under NASA contract NAS5-26555. Other collaborators include Francisco Mercado, Courtney Klein and Zachary Hafen, all from UCI.

- How life came to Earth

Date: February 10, 2022
Source: Friedrich-Schiller-Universitaet Jena

Researchers have discovered a new clue in the search for the origin of life by showing that peptides can form on dust under conditions such as those prevailing in outer space. These molecules, which are one of the basic building blocks of all life, may therefore not have originated on our planet at all, but possibly in cosmic molecular clouds.

Chains of amino acids

All life as we know it consists of the same chemical building blocks. These include peptides, which perform various completely different functions in the body -- transporting substances, accelerating reactions or forming stabilising scaffolds in cells. Peptides consist of individual amino acids arranged in a specific order. The exact order determines a peptide's eventual properties.

How these versatile biomolecules came into being is one of the questions about the origin of life. Amino acids, nucleobases and various sugars found in meteoroids, for example, show that this origin could be extra-terrestrial in nature. However, for a peptide to be formed from individual amino acid molecules, very special conditions are required that were previously assumed to be more likely to exist on Earth.

The first step requires water, while for the second step, there must be no water

"Water plays an important role in the conventional way in which peptides are created," says Dr Serge Krasnokutski of the Laboratory Astrophysics and Cluster Physics Group of the Max Planck Institute for Astronomy at the University of Jena. In this process, individual amino acids combine to

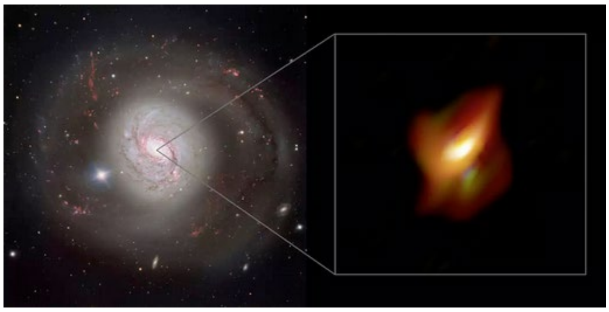
form a chain. For this to happen, one water molecule must be removed each time. "Our quantum chemical calculations have now shown that the amino acid glycine can be formed through a chemical precursor -- called an amino ketene -- combining with a water molecule. Put simply: in this case, water must be added for the first reaction step, and water must be removed for the second."
With this knowledge, the team led by the physicist Krasnokutski has now been able to demonstrate a reaction pathway that can take place under cosmic conditions and does not require water.
"Instead of taking the chemical detour in which amino acids are formed, we wanted to find out whether amino ketene molecules could not be formed instead and combine directly to form peptides," says Krasnokutski, describing the basic idea behind the work. He adds: "And we did this under the conditions that prevail in cosmic molecular clouds, that is to say on dust particles in a vacuum, where the corresponding chemicals are present in abundance: carbon, ammonia and carbon monoxide."
In an ultra-high vacuum chamber, substrates that serve as a model for the surface of dust particles were brought together with carbon, ammonia and carbon monoxide at about one quadrillionth of normal air pressure and minus 263 degrees Celsius.
"Investigations showed that under these conditions, the peptide polyglycine was formed from the simple chemicals," Krasnokutski says. "These are therefore chains of the very simple amino acid glycine, and we observed different lengths. The longest specimens consisted of eleven units of the amino acid."
In this experiment, the german team was also able to detect the suspected amino ketene.
"The fact that the reaction can take place at such low temperatures at all is due to the amino ketene molecules being extremely reactive. They combine with each other in an effective polymerisation. The product of this is polyglycine."

Quantum mechanical tunnelling effect might play a role

"It was nevertheless surprising to us that the polymerisation of amino ketene could happen so easily under such conditions," says Krasnokutski. "This is because an energy barrier actually has to be overcome for this to happen. However, it may be that we are helped in this by a special effect of quantum mechanics. In this special reaction step, a hydrogen atom changes its place. However, it is so small that, as a quantum particle, it could not overcome the barrier but was simply able to cross it, so to speak, through the tunnelling effect."
Now that it is clear that not only amino acids, but also peptide chains, can be created under cosmic conditions, we may have to look not only to Earth but also more into space when researching the origin of life.

- Supermassive black hole caught hiding in a ring of cosmic dust

Date: February 16, 2022
Source: ESO



The left panel of this image shows a dazzling view of the active galaxy NGC 1068 captured with the Focal Reducer and low dispersion Spectrograph 2 (FORS2) instrument on ESO’s Very Large Telescope (VLT). The right panel shows a blow-up view of the very inner region of this galaxy, its active galactic nucleus, as seen with the MATISSE instrument on ESO’s Very Large Telescope Interferometer (VLTI) at infrared wavelengths. (Image: ESO/Jaffe, Gámez-Rosas et al.)

The European Southern Observatory's Very Large Telescope Interferometer (ESO's VLTI) has observed a cloud of cosmic dust at the centre of the galaxy Messier 77 that is hiding a supermassive black hole. The findings have confirmed predictions made around 30 years ago and are giving astronomers new insight into "active galactic nuclei," some of the brightest and most enigmatic objects in the universe.
Active galactic nuclei (AGNs) are extremely energetic sources powered by supermassive black holes and found at the centre of some galaxies. These black holes feed on large volumes of cosmic dust and gas. Before it is eaten up, this material spirals towards the black hole and huge amounts of energy are released in the process, often outshining all the stars in the galaxy.
Astronomers have been curious about AGNs ever since they first spotted these bright objects in the 1950s. Now, thanks to ESO's VLTI, a team of researchers, led by Violeta Gámez Rosas from Leiden University in the Netherlands, have taken a key step towards understanding how they work and what they

look like up close. The results are published today in *Nature*.

By making extraordinarily detailed observations of the centre of the galaxy Messier 77, also known as NGC 1068, Gámez Rosas and her team detected a thick ring of cosmic dust and gas hiding a supermassive black hole. This discovery provides vital evidence to support a 30-year-old theory known as the Unified Model of AGNs.

Astronomers know there are different types of AGN. For example, some release bursts of radio waves while others don't; certain AGNs shine brightly in visible light, while others, like Messier 77, are more subdued. The Unified Model states that despite their differences, all AGNs have the same basic structure: a supermassive black hole surrounded by a thick ring of dust.

According to this model, any difference in appearance between AGNs results from the orientation at which we view the black hole and its thick ring from Earth. The type of AGN we see depends on how much the ring obscures the black hole from our view point, completely hiding it in some cases.

Astronomers had found some evidence to support the Unified Model before, including spotting warm dust at the centre of Messier 77. However, doubts remained about whether this dust could completely hide a black hole and hence explain why this AGN shines less brightly in visible light than others.

"The real nature of the dust clouds and their role in both feeding the black hole and determining how it looks when viewed from Earth have been central questions in AGN studies over the last three decades," explains Gámez Rosas. "Whilst no single result will settle all the questions we have, we have taken a major step in understanding how AGNs work."

The observations were made possible thanks to the Multi AperTure mid-Infrared Spectroscopic Experiment (MATISSE) mounted on ESO's VLTI, located in Chile's Atacama Desert. MATISSE combined infrared light collected by all four 8.2-metre telescopes of ESO's Very Large Telescope (VLT) using a technique called interferometry. The team used MATISSE to scan the centre of Messier 77, located 47 million light-years away in the constellation Cetus.

"MATISSE can see a broad range of infrared wavelengths, which lets us see through the dust and accurately measure temperatures. Because the VLTI is in fact a very large interferometer, we have the resolution to see what's going on even in galaxies as far away as Messier 77. The images we obtained detail the changes in temperature and absorption of the dust clouds around the black hole," says co-author Walter Jaffe, a professor at Leiden University.

Combining the changes in dust temperature (from around room temperature to about 1200 °C) caused by the intense radiation from the black hole with the absorption maps, the team built up a detailed picture of the dust and pinpointed where the black hole must lie. The dust -- in a thick inner ring and a more extended disc -- with the black hole positioned at its centre supports the Unified Model. The team also used data from the Atacama Large Millimetre/submillimetre Array, co-owned by ESO, and the National Radio Astronomy Observatory's Very Long Baseline Array to construct their picture.

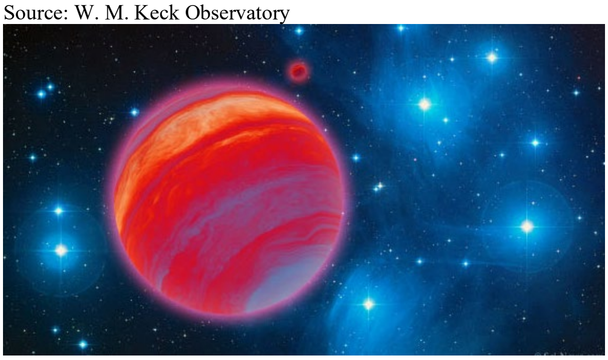
"Our results should lead to a better understanding of the inner workings of AGNs," concludes Gámez Rosas. "They could also help us better understand the history of the Milky Way, which harbours a supermassive black hole at its centre that may have been active in the past."

The researchers are now looking to use ESO's VLTI to find more supporting evidence of the Unified Model of AGNs by considering a larger sample of galaxies.

Team member Bruno Lopez, the MATISSE Principal Investigator at the Observatoire de la Côte d'Azur in Nice, France, says: "Messier 77 is an important prototype AGN and a wonderful motivation to expand our observing programme and to optimise MATISSE to tackle a wider sample of AGNs."

- Astronomers discover widest separation of brown dwarf pair to date

Date: February 17, 2022
Source: W. M. Keck Observatory



An artist's impression of a pair of brown dwarfs in the Pleiades cluster. Image credit: Sci-News.com / NASA / ESA / AURA / Caltech.

A team of astronomers has discovered a rare pair of brown dwarfs that has the widest separation of any brown dwarf binary system found to date.

"Because of their small size, brown dwarf binary systems are usually very close together," said Emma Softich, an undergraduate astrophysics student at the Arizona State University (ASU) School of Earth and Space Exploration and lead author of the study. "Finding such a widely separated pair is very exciting."

The gravitational force between a pair of brown dwarfs is lower than for a pair of stars with the same separation, so wide brown dwarf binaries are more likely to break up over time, making this pair of brown dwarfs an exceptional find.

The study, which is based on observations the University of California San Diego (UC San Diego) Cool Star Lab conducted with W. M. Keck Observatory on Maunakea, Hawai'i Island, is published in today's issue of *The Astrophysical Journal Letters*.

Using Keck Observatory's Near-Infrared Echellette Spectrometer, or NIRES instrument, members of the UC San Diego Cool Star Lab, including Physics Professor Adam Burgasser and graduate students Christian Aganze and Dino Hsu, obtained infrared spectra of the brown dwarf binary system, called CWISE J014611.20-050850.0AB. The data revealed the two brown dwarfs are about 12 billion miles apart, or three times the separation of Pluto from the Sun. This distance confirms the unusual brown dwarf couple breaks the record for having the widest separation from each other.

"Keck's exceptional sensitivity in the infrared with this instrument was critical for our measurements," said co-author Burgasser, who leads the Cool Star Lab. "The secondary brown dwarf of this system is exceptionally faint, but with Keck we were able to obtain good enough spectral data to classify both sources and identify them as members of a rare class of blue L dwarfs."

"Wide, low-mass systems like CWISE J014611.20-050850.0AB are usually disrupted early on in their lifetimes, so the fact that this one has survived until now is pretty remarkable," said co-author Adam Schneider of the U.S. Naval Observatory, Flagstaff Station and George Mason University.

Brown dwarfs are celestial objects that are smaller than a normal star. These objects are not massive enough to sustain nuclear fusion and shine like normal stars, but are hot enough to radiate energy.

Many brown dwarfs have been discovered with data from NASA's Wide-field Infrared Survey Explorer (WISE) via the Backyard Worlds: Planet 9 citizen science project, which solicits help from the public to search the WISE image data bank to find brown dwarfs and low-mass stars, some of the Sun's nearest neighbours.

For this study, the researchers inspected images of Backyard Worlds discoveries, where companion brown dwarfs may have been overlooked. In doing so, they discovered the rare CWISE J014611.20 050850.0AB brown dwarf binary system.

Softich went through about 3,000 brown dwarfs from Backyard Worlds one by one and compared the WISE images to other survey images, looking for evidence of a brown dwarf companion to the original target. The team then used data from the Dark Energy Survey (DES) to confirm that it was indeed a brown dwarf pair.

They then used Keck Observatory's NIRES to confirm the brown dwarfs have spectral types L4 and L8, and that they are at an estimated distance of about 40 parsecs, or 130.4 light-years from Earth, with a projected separation of 129 astronomical units, or 129 times the distance between the Sun and the Earth.

The team hopes this discovery will allow astronomers the chance to study brown dwarf binary systems and to develop models and procedures that will help in recognizing more of them in the future.

"Binary systems are used to calibrate many relations in astronomy, and this newly discovered pair of brown dwarfs will present an important test of brown dwarf formation and evolution models," said co-author Jennifer Patience, Softich's adviser at ASU.

- Ancient dwarf galaxy reconstructed with MilkyWay@home volunteer computer

Date: February 17, 2022
Source: Rensselaer Polytechnic Institute


An artist's impression of a dwarf galaxy. Image credit: Rensselaer Polytechnic Institute

Astrophysicists for the first time have calculated the original mass and size of a dwarf galaxy that was shredded in a collision with the Milky Way billions of years ago. Reconstructing the original dwarf galaxy, whose stars today thread through the Milky Way in a stellar "tidal stream," will help scientists understand how galaxies like the Milky Way formed, and could aid in the search for dark matter in our galaxy.

"We've been running simulations that take this big stream of stars, back it up for a couple of billion years, and see what it looked like before it fell into the Milky Way," said Heidi Newberg, a professor of physics, astrophysics, and astronomy at Rensselaer Polytechnic Institute. "Now we have a measurement from data, and it's the first big step toward using the information to find dark matter in the Milky Way."

Billions of years ago, the dwarf galaxy and others like it near the Milky Way were pulled into the larger galaxy. As each dwarf galaxy coalesced with the Milky Way, its stars were pulled by "tidal forces," the same kind of differential forces that make tides on Earth. The tidal forces distorted and eventually ripped the dwarf galaxy apart, stretching its stars into a tidal stream flung across the Milky Way. Such tidal mergers are fairly common, and Newberg estimates that "immigrant" stars absorbed into the Milky Way make up most of the stars in the galactic halo, a roughly spherical cloud of stars that surrounds the spiral arms of the central disk.

Critically, the position and velocities of the tidal stream stars carry information about the Milky Way's gravitational field.

Reconstructing the dwarf galaxy is a research task that combines data from star surveys, physics, and Newberg's MilkyWay@Home distributed supercomputer, which harnesses 1.5 petaflops -a measure of computer processing speed- of home computer power donated by volunteers. This large amount of processing power makes it possible to simulate the destruction of a large number of dwarf galaxies with different shapes and sizes, and identify a model that best matches the tidal stream of stars that we see today.

"It's an enormous problem, and we solve it by running tens of thousands of different simulations until we get one that actually matches. And that takes a lot of computer power, which we get with the help of volunteers all over the world who are part of MilkyWay@Home," Newberg said "We're brute-forcing it, but given how complicated the problem is, I think this method has a lot of merit."

As published today in *The Astrophysical Journal*, Newberg's team estimates the total mass of the original galaxy whose stars today form the Orphan-Chenab Stream as $2x10^7$ times the mass of our sun.

However, only a little more than 1% of that mass is estimated to be made up of ordinary matter like stars. The remainder is assumed to be a hypothetical substance called dark matter that exerts gravitational force, but that we cannot see because it does not absorb or give off light. The existence of dark matter would explain a discrepancy between the gravitational pull of the mass of the matter we can see, and the far larger pull needed to account for the formation and movement of galaxies. The gravitational pull from dark matter is estimated to make up as much as 85% of the matter in the universe, and tidal streams of stars that fell in with dwarf galaxies could be used to determine where dark matter is located in our galaxy.

"Tidal stream stars are the only stars in our galaxy for which it is possible to know their positions in the past," Dr. Newberg said. "By looking at the current speeds of stars along a tidal stream, and knowing they all used to be in about the same place and moving at the same speed, we can figure out how much the gravity changes along that stream. And that will tell us where the dark matter is in the Milky Way."

The research also finds that the progenitor of the Orphan-Chenab stream has less mass than the galaxies measured in the outskirts of our galaxy today, and if this small mass is confirmed it could change our understanding of how small stellar systems form and then merge together to make larger galaxies like our Milky Way.

Dr. Newberg, an expert in the galactic halo, is a pioneer in identifying stellar tidal streams in the Milky Way. One day, she hopes that MilkyWay@home will help her measure more than the properties of one disintegrated dwarf galaxy. Ideally, she would like to simultaneously fit many dwarf galaxies, their orbits, and the properties of the Milky Way galaxy itself. This goal is complicated by the fact that the properties of our galaxy change over the billions of years that it takes for a small galaxy to fall in and be ripped apart to make these tidal streams.

"By painstakingly tracking the path of stars pulled into the Milky Way, Dr. Newberg and her team are building an image that shows us not just a dwarf galaxy long-since destroyed, but also sheds light on the formation of our galaxy and the very nature of matter," said Curt Breneman, dean of the Rensselaer School of Science.

At Rensselaer, Newberg was joined in the research by Eric J. Mendelsohn, Siddhartha Shelton, Jeffery M. Thompson. Carl J. Grillmair at the California Institute of Technology, and Lawrence M. Widrow at Queen's University, also contributed to the finding. "*Estimate of the Mass and Radial Profile of the Orphan-Chenab Stream's Dwarf Galaxy Progenitor Using MilkyWay@home*" was published with support from the National Science Foundation, and with data from the Sloan Digital Sky Survey, the Dark Energy Camera at the Cerro Tololo Inter-American Observatory, and the National Aeronautics and Space Administration/Infrared Processing & Analysis Centre Infrared Science Archive.

- Debris from disintegrating planets hurtling into white dwarfs across the galaxy

Date: February 10, 2022
Source: University of Warwick

Artist's impression of a white dwarf, G29—38, accreting planetary material from a circumstellar debris disk. When the planetary material hits the white dwarf surface, a plasma is formed and cools via detectable X-ray emission. Credit: University of Warwick/Mark Garlick

The moment that debris from destroyed planets impacts the surface of a white dwarf star has been observed for the first time by astronomers at the University of Warwick. They have used X-rays to detect the rocky and gaseous material left behind by a planetary system after its host star dies as it collides and is consumed within the surface of the star.

Published today (9 February) in the journal *Nature*, the results are the first direct measurement of the accretion of rocky material onto a white dwarf, and confirm decades of indirect evidence of accretion in over a thousand stars so far. The observed event occurred billions of years after the formation of the planetary system.

The fate of most stars, including those like our Sun, is to become a white dwarf. Over 300,000 white dwarf stars have been discovered in our galaxy, and many are believed to be accreting the debris from planets and other objects that once orbited them.

For several decades, astronomers have used spectroscopy at optical and ultraviolet wavelengths to measure the abundances of elements on the surface of the star and work out from that the composition of the object it came from. Astronomers have indirect evidence that these objects are actively accreting from spectroscopic observations, which show 25-50% of white dwarfs with heavy elements such as iron, calcium, magnesium polluting their atmospheres.

Until now though, astronomers had not seen the material as it was pulled into the star.

Dr Tim Cunningham of the University of Warwick Department of Physics said: "We have finally seen material actually entering the star's atmosphere. It is the first time we've been able to derive an accretion rate that doesn't depend on detailed models of the white dwarf atmosphere. What's quite remarkable is that it agrees extremely well with what's been done before.

"Previously, measurements of accretion rates have used spectroscopy and have been dependent on white dwarf models. These are numerical models that calculate how quickly an element sinks out of the atmosphere into the star, and that tells you how much is falling into the atmosphere as an accretion rate. You can then work backwards and work out how much of an element was in the parent body, whether a planet, moon or asteroid."

A white dwarf is a star that has burnt up all its fuel and shed its outer layers, potentially destroying or unsettling any orbital bodies in the process. As material from those bodies is pulled into the star at a high enough rate it slams into the surface of the star, forming a shock-heated plasma. This plasma, with a temperature between 100,000 to a million degrees kelvin, then settles on the surface, and as it cools it emits X-rays that can be detected.

X-rays are similar to the light our eyes can see, but have much more energy. They are created by very fast-moving electrons (the outer shells of atoms, which make up all the matter around us). Commonly known for their use in medicine, in astronomy X-rays are the key fingerprint of material raining down on exotic objects such as black holes and neutron stars.

Detecting these X-rays is very challenging as the small amount that reaches Earth can be lost amongst other bright X-ray sources in the sky. So the astronomers took advantage of the Chandra X-ray Observatory, normally used to detect X-rays from black holes and neutron stars that are accreting, to analyse the nearby white dwarf G29-38.

With Chandra's improved angular resolution over other telescopes they could isolate the target star from other X-ray sources and viewed, for the first time, X-rays from an isolated white dwarf. It confirms decades of observations of material accreting into white dwarfs that have relied upon evidence from spectroscopy.

Dr Cunningham adds: "What's really exciting about this result is that we're working at a different wavelength, X-rays, and that allows us to probe a completely different type of physics.

"This detection provides the first direct evidence that white dwarfs are currently accreting the remnants of old planetary systems. Probing accretion in this way provides a new technique by which we can study these systems, offering a glimpse into the likely fate of the thousands of known exoplanetary systems, including our own Solar system."

- Surprisingly high fraction of dead galaxies found in ancient galactic city

Why cluster's galaxies are unlike those in all the other known protoclusters is a mystery

Date: February 9, 2022
Source: University of California – Riverside

This artist's impression depicts the formation of a galaxy cluster in the early Universe. The galaxies are vigorously forming new stars and interacting with each other. Such a scene closely resembles the Spiderweb Galaxy (formally known as MRC 1138-262) and its surroundings, which is one of the best-studied protoclusters. Credit: ESO/M. Kornmesser

An international team of astronomers led by researchers at the University of California, Riverside, has discovered an unusual massive cluster of young galaxies forming in the early universe. The newly discovered growing galactic metropolis, named MAGAZ3NE J095924+022537, is a new born galaxy cluster, or protocluster, consisting of at least 38 member galaxies, and is about 11.8 billion light-years away from Earth.

Galaxy clusters grow over time under gravity and, in the present-day universe, can contain hundreds or even thousands of galaxies, as well as hot gas and dark matter. As time goes by, their galaxies burn through the fuel available and evolve from vigorously star-forming galaxies into red and dead galaxies.

"In the early universe, all protoclusters discovered until now are full of vigorously star-forming galaxies," said Ian McConachie, a graduate student in the UC Riverside Department of Physics and Astronomy and the lead author of the research paper published in the *Astrophysical Journal*. "But incredibly, unlike all of the other protoclusters that have been found at this epoch, many galaxies in MAGAZ3NE J0959 appear to have already stopped forming stars."

Co-author Gillian Wilson, a professor of physics and astronomy at UCR in whose lab McConachie works, said J0959 was discovered from the "Massive Ancient Galaxies At Z > 3 NEar-infrared," or MAGAZ3NE, survey, designed to discover and study ultra massive galaxies and their neighbours.

"We are seeing this protocluster as it appeared when the universe was less than 2 billion years old," she said. "It is as if you took a cluster like Coma, the nearest rich cluster of galaxies to Earth, and plopped it into the early universe."
Co-author Benjamin Forrest, a former postdoctoral researcher in Wilson's lab who is now based at UC Davis, explained that at the heart of MAGAZ3NE J0959 is an ultra-massive galaxy that has already formed a mass of more than 200 billion suns.
"Why this ultra massive galaxy and so many of its neighbours formed most of their stars and then became inactive when the universe was still so young, in contrast to other known protoclusters from the same time, is a big mystery," he said. "Why its galaxies are so unlike those in all the other known protoclusters, and so similar to those in Coma, is a complete mystery."
Forrest added that MAGAZ3NE J0959 was discovered from the ground, but the advent of powerful new capabilities, like the recently-launched James Webb Space Telescope, should soon reveal whether there are other protoclusters like MAGAZ3NE J0959 packed with dead galaxies waiting to be found in the early universe.
"Should such protoclusters be found in large numbers, it would mean that the current paradigm of protocluster formation would require a major revision," Forrest said. "A new scenario of protoclusters existing in a diversity of states in the early universe would have to be adopted. With many member galaxies quenching in the first two billion years, this would almost certainly pose significant challenges for current models of galaxy simulation."
The team used spectroscopic observations from the W. M. Keck Observatory's Multi-Object Spectrograph for Infrared Exploration, or MOSFIRE, to make detailed measurements of MAGAZ3NE J0959 and precisely quantify its distances.
Closely associated to the question of how ultra massive galaxies form is the question of the environment in which they form, for example, are they always found in over dense environments like protoclusters, or can they also form in isolation? Next, the team plans to study the neighbourhood of all other ultra massive galaxies in the MAGAZ3NE survey to answer this question.
Other researchers involved in the study are Cemile Marsan and Adam Muzzin of York University, Canada; Michael Cooper of UC Irvine; Marianna Annunziatella and Danilo Marchesini of Tufts University; Jeffrey Chan and Mohamed Abdullah of UCR; Percy Gomez of Keck Observatory; Paolo Saracco of Astronomical Observatory of Brera, Italy; Julie Nantais of Andrés Bello National University, Santiago, Chile.
The study was supported by grants from the National Science Foundation and NASA.

- ❖ Juno and Hubble data reveal electromagnetic 'tug-of-war' lights up Jupiter’s upper atmosphere

Date: February 3, 2022
Source: University of Leicester


Composite image of two different Hubble observations. The aurorae were photographed during a series of Hubble Space Telescope Imaging Spectrograph far-ultraviolet-light observations taking place as NASA's Juno spacecraft approaches and enters into orbit around Jupiter. The full-colour disk of Jupiter in this image was separately photographed at a different time by Hubble’s Outer Planet Atmospheres Legacy (OPAL) program, a long-term Hubble project that annually captures global maps of the outer planets. Credit: NASA, ESA, and J. Nichols (University of Leicester)

New Leicester space research has revealed, for the first time, a complex 'tug-of-war' lights up aurorae in Jupiter's upper atmosphere, using a combination of data from NASA's Juno probe and the Hubble Space Telescope.
The study, published in the *Journal of Geophysical Research: Space Physics*, describes the delicate current cycle driven by Jupiter's rapid rotation and the release of sulphur and oxygen from volcanoes on its moon, Io.
Researchers from the University of Leicester's School of Physics and Astronomy used data from Juno's Magnetic Field Investigation (MAG), which measures Jupiter's magnetic field from orbit around the gas giant, and observations from the Space Telescope Imaging Spectrograph carried by the Hubble Space Telescope.
Their research provides the strongest evidence yet that Jupiter's powerful aurorae are associated with an electric current system that acts as part of a tug-of-war with material in the

magnetosphere, the region dominated by the planet's enormous magnetic field.
Dr Jonathan Nichols is a Reader in Planetary Auroras at the University of Leicester and corresponding author for the study. He said:
"We've had theories linking these electric currents and Jupiter's powerful auroras for over two decades now, and it was so exciting to be able to finally test them by looking for this relationship in the data. And when we plotted one against the other I nearly fell off my chair when I saw just how clear the connection is.
"It's thrilling to discover this relation because it not only helps us understand how Jupiter's magnetic field works, but also those of planets orbiting other stars, for which we have previously used the same theories, and now with renewed confidence."
Despite its huge size -- with a diameter more than 11 times that of Earth -- Jupiter rotates once approximately every nine-and-a-half hour.
Io is a similar size and mass to Earth's moon, but orbits Jupiter at an average distance of 422,000 km; roughly 10% further away. With over 400 active volcanoes, Io is the most geologically active object in the Solar System.
Scientists had long suspected a relationship between Jupiter's aurorae and the material ejected from Io at a rate of many hundreds of kilograms per second, but the data captured by Juno proved ambiguous.
Dr Scott Bolton, of NASA's Jet Propulsion Laboratory (JPL), is Principal Investigator (PI) for the Juno mission. He said:
"These exciting results on how Jupiter's aurorae work are a testament to the power of combining Earth-based observations from Hubble with Juno measurements. The HST images provide the broad overview, while Juno investigates close up. Together they make a great team!"
Much of the material released from Io is propelled away from Jupiter by the planet's rapidly rotating magnetic field, and as it moves outward its rotation rate tends to slow down. This results in an electromagnetic tug-of-war, in which Jupiter attempts to keep this material spinning at its rotation speed via a system of electric currents flowing through the planet's upper atmosphere and magnetosphere.
The component of the electric current flowing out of the planet's atmosphere, carried by electrons fired downward along magnetic field lines into the upper atmosphere, was thought to drive Jupiter's main auroral emission. However, prior to Juno's arrival this idea had never been tested, as no spacecraft with relevant instruments had previously orbited close enough to Jupiter. And when Juno arrived in 2016, the expected signature of such an electric current system was not reported -- and, while such signatures have since been found -- one of the great surprises of Juno's mission has been to show that the nature of the electrons above Jupiter's polar regions is much more complex than was initially expected.
The researchers compared the brightness of Jupiter's main auroral emission with simultaneous measurements of the electric current flowing away from the Solar System's largest planet in the magnetosphere over an early part of Juno's mission.
These aurorae were observed with instruments on board the Hubble Space Telescope, in Earth orbit. By comparing the dawn-side measurements of current with the brightness of Jupiter's aurorae, the team demonstrated the relationship between the auroral intensity and magnetospheric current strength.
Stan Cowley is Emeritus Professor of Solar-Planetary Physics at the University of Leicester and co-author for the study, and has studied Jupiter's powerful aurorae for 25 years. Professor Cowley added:
"Having more than five years of in-orbit data from the Juno spacecraft, together with auroral imaging data from the HST, we now have the material to hand to look in detail at the overall physics of Jupiter's outer plasma environment, and more is to come from Juno's extended mission, now in progress. We hope our present paper will be followed by many more exploring this treasure trove for new scientific understanding."

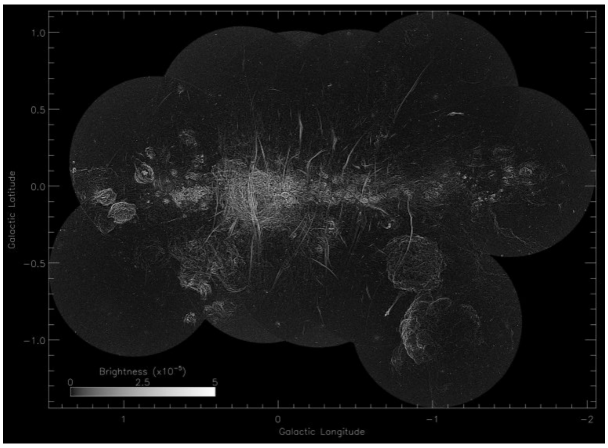
- Astronomers offer theory about mysterious location of massive stars

Researchers found the secret seems to lie in the merging of medium-mass stars
Date: February 2, 2022
Source: Georgia State University

Astronomers from Georgia State University have found an explanation for the strange occurrence of massive stars located far from their birthplace in the disk of our Milky Way Galaxy.
Stars more massive than the Sun have very hot cores that drive nuclear energy generation at very high rates. They are among the brightest objects in our galaxy. But because they burn through their hydrogen fuel so quickly, their lifetimes are relatively short, perhaps 10 million years compared to 10 billion years for the Sun.
Their short lifetime means that there is little time for them to stray too far from their birthplace. Most massive stars are found in the flat disk part of our galaxy, where gas clouds are dense enough to promote star birth and where astronomers find young clusters of massive stars.
So, when a massive star is found far away from the galaxy's disk, how did it get there?
"Astronomers are finding massive stars far away from their place of origin, so far, in fact, that it takes longer than the star's lifetime to get there," said Georgia State astronomer Douglas Gies. "How this could happen is a topic of active debate among scientists."
This is the problem presented by the massive star known as HD93521 that lies about 3,600 light years above the galaxy's disk. A new study by Gies and other astronomers from Georgia State reveals a profound discrepancy: The flight time to reach this location far exceeds the predicted age of this massive star.
The astronomers used a new distance estimate from the European Space Agency's Gaia spacecraft together with an investigation of the star's spectrum to determine the star's mass and age as well as its motion through space. They find that HD93521 has a mass about 17 times larger than the Sun's, and this leads to a predicted age of about 5 million years. On the other hand, the motion of the star indicates that its journey from the disk has taken much longer, about 39 million years.
The Georgia State astronomers explain this strange difference between the star's lifetime and travel time by suggesting that HD93521 left the disk as two lower-mass and longer-lived stars, rather than the single massive star we see today. Their findings have been published in *The Astronomical Journal.*
The clue to the mystery is that HD93521 is one of the fastest rotating stars in the galaxy. Stars can spin up through stellar mergers where two close orbiting stars can grow over time and collide to form one star.
"HD93521 probably began life as a close pair of medium-mass stars that were fated to engulf each other and create the single, fast-spinning star we see today," Gies said.
Such intermediate mass stars live long enough to match the long flight time of HD93521.
HD93521 is not the only case of a massive star found so far away from its birthplace. Georgia State graduate student Peter Wysocki is investigating an example of a distant massive binary pair that is probably representative of the stage just before a merger. This star is known as IT Librae, and it has an orientation that creates mutual eclipses as the two stars pass in front of each other. An investigation of the variations in the light output and motions detected in the spectra leads to estimates of the stellar masses.
Wysocki finds a similar conundrum from the mass results -- the predicted age is much less than IT Librae's travel time from the disk. But the study also reveals that the lower-mass star in the pair has already begun to transfer much of its mass to the higher-mass star, initiating the process that may eventually lead to a merger. This means that the higher-mass star is actually older than it appears, having begun life as a lower-mass star.
These distant massive stars provide striking evidence that close pairs of stars can merge to make even larger stars, Gies said, and they are key clues about how rapidly rotating massive stars are able to create black holes with large spins.
This work was supported through a grant from the National Science Foundation.

- Nearly 1,000 mysterious strands revealed in Milky Way's centre

'A watershed in furthering our understanding of these structures,' researcher says
Date: February 2, 2022
Source: Northwestern University



A mosaic radio image of the Milky Way galaxy's centre with the background removed to isolate the magnetic filaments. The filaments are large, vertical slashes throughout the image. Credit: Farhad Yusef-Zadeh/Northwestern University

An unprecedented new telescope image of the Milky Way galaxy's turbulent centre has revealed nearly 1,000 mysterious strands, inexplicably dangling in space.

Stretching up to 150 light years long, the one-dimensional strands (or filaments) are found in pairs and clusters, often stacked equally spaced, side by side like strings on a harp.

Using observations at radio wavelengths, Northwestern University's Farhad Yusef-Zadeh discovered the highly organized, magnetic filaments in the early 1980s. The mystifying filaments, he found, comprise cosmic ray electrons gyrating the magnetic field at close to the speed of light. But their origin has remained an unsolved mystery ever since.

Now, the new image has exposed 10 times more filaments than previously discovered, enabling Yusef-Zadeh and his team to conduct statistical studies across a broad population of filaments for the first time. This information potentially could help them finally unravel the long-standing mystery.

The study was published online today by *The Astrophysical Journal Letters.*

"We have studied individual filaments for a long time with a myopic view," said Yusef-Zadeh, the paper's lead author. "Now, we finally see the big picture -- a panoramic view filled with an abundance of filaments. Just examining a few filaments makes it difficult to draw any real conclusion about what they are and where they came from. This is a watershed in furthering our understanding of these structures."

Yusef-Zadeh is a professor of physics and astronomy at Northwestern's Weinberg College of Arts and Sciences and a member of the Centre for Interdisciplinary Exploration and Research in Astrophysics (CIERA).

Constructing the image

To construct the image with unprecedented clarity and detail, astronomers spent three years surveying the sky and analysing data at the South African Radio Astronomy Observatory (SARAO). Using 200 hours of time on SARAO's MeerKAT telescope, researchers pieced together a mosaic of 20 separate observations of different sections of the sky toward the centre of the Milky Way galaxy, 25,000 light years from Earth.

The full image will be published in an additional, accompanying paper -- led by Oxford University astrophysicist Ian Heywood and co-authored by Yusef-Zadeh -- in a forthcoming issue of The Astrophysical Journal. Along with the filaments, the image captures radio emissions from numerous phenomena, including out bursting stars, stellar nurseries and new supernova remnants.

"I've spent a lot of time looking at this image in the process of working on it, and I never get tired of it," Heywood said. "When I show this image to people who might be new to radio astronomy, or otherwise unfamiliar with it, I always try to emphasize that radio imaging hasn't always been this way, and what a leap forward MeerKAT really is in terms of its capabilities. It's been a true privilege to work over the years with colleagues from SARAO who built this fantastic telescope."

To view the filaments at a finer scale, Yusef-Zadeh's team used a technique to remove the background from the main image in order to isolate the filaments from the surrounding structures. The resulting picture astounded him.

"It's like modern art," he said. "These images are so beautiful and rich, and the mystery of it all makes it even more interesting."

What we know

While many mysteries surrounding the filaments remain, Yusef-Zadeh has been able to piece together more of the puzzle. In their latest paper, he and his collaborators specifically explored the filaments' magnetic fields and the role of cosmic rays in illuminating the magnetic fields.

The variation in radiation emitting from the filaments is very different from that of the newly uncovered supernova remnant, suggesting that the phenomena have different origins. It is more likely, the researchers found, that the filaments are related to past activity of the Milky Way's central supermassive black hole rather than coordinated bursts of supernovae. The filaments also could be related to enormous, radio-emitting bubbles, which Yusef-Zadeh and collaborators discovered in 2019.

And, while Yusef-Zadeh already knew the filaments are magnetized, now he can say magnetic fields are amplified along the filaments, a primary characteristic all the filaments share.

"This is the first time we have been able to study statistical characteristics of the filaments," he said. "By studying the statistics, we can learn more about the properties of these unusual sources.

"If you were from another planet, for example, and you encountered one very tall person on Earth, you might assume all people are tall. But if you do statistics across a population of people, you can find the average height. That's exactly what we're doing. We can find the strength of magnetic fields, their lengths, their orientations and the spectrum of radiation."

What we don't know

Among the remaining mysteries, Yusef-Zadeh is particularly puzzled by how structured the filaments appear. Filaments within clusters are separated from one another at perfectly equal distances -- about the distance from Earth to the sun.

"They almost resemble the regular spacing in solar loops," he said. "We still don't know why they come in clusters or understand how they separate, and we don't know how these regular spacings happen. Every time we answer one question, multiple other questions arise."

Yusef-Zadeh and his team also still don't know whether the filaments move or change over time or what is causing the electrons to accelerate at such incredible speeds.

"How do you accelerate electrons at close to the speed of light?" he asked. "One idea is there are some sources at the end of these filaments that are accelerating these particles."

What's next

Yusef-Zadeh and his team are currently identifying and cataloguing each filament. The angle, curve, magnetic field, spectrum and intensity of each filament will be published in a future study. Understanding these properties will give the astrophysics community more clues into the filaments' elusive nature.

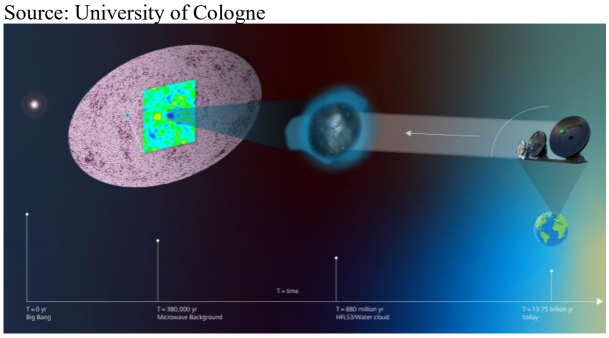
The MeerKAT telescope, which launched in July 2018, will continue to unveil new secrets.

"We're certainly one step closer to a fuller understanding," Yusef-Zadeh said. "But science is a series of progress on different levels. We're hoping to get to the bottom of it, but more observations and theoretical analyses are needed. A full understanding of complex objects takes time."

The study, "Statistical properties of the population of the galactic centre filaments: The spectral index and equipartition magnetic field," was supported by NASA and the National Science Foundation.

- ❖ Shadow of cosmic water cloud reveals the temperature of the young universe

Date: February 2, 2022
Source: University of Cologne



The Cosmic Microwave Background (left) was released 380,000 years after the Big Bang, and it acts as a background to all galaxies in the Universe. The starburst galaxy HFLS3 is embedded in a large cloud of cold water vapor (middle, indicated in blue), and is observed 880 million years after the Big Bang. Because of its low temperature, the water casts a dark shadow on the Microwave background (zoom-in panel on the left), corresponding to a contrast about 10,000 times stronger than its intrinsic fluctuations of only 0.001% (light/dark spots). Credit: ESA and the Planck collaboration; zoom-in panel: Dominik Riechers, University of Cologne; image composition: Martina Markus, University of Cologne

An international group of astrophysicists has discovered a new method to estimate the cosmic microwave background temperature of the young Universe only 880 million years after the Big Bang. It is the first time that the temperature of the cosmic microwave background radiation -- a relic of the energy released by the Big Bang -- has been measured at such an early epoch of the Universe. The prevailing cosmological model assumes that the Universe has cooled off since the Big Bang -- and still continues to do so. The model also describes how the cooling process should proceed, but so far it has only been directly confirmed for relatively recent cosmic times. The discovery not only sets a very early milestone in the development of the cosmic background temperature, but could also have implications for the enigmatic dark energy.

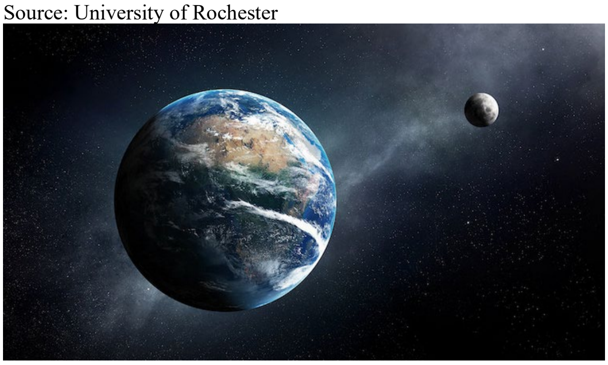
The article 'Microwave background temperature at a redshift of 6.34 from H_2O absorption' was published in *Nature* today.

The scientists used the NOEMA (Northern Extended Millimetre Array) observatory in the French Alps, the most powerful radio telescope in the Northern Hemisphere, to

observe HFLS3, a massive starburst galaxy at a distance corresponding to an age of only 880 million years after the Big Bang. They discovered a screen of cold water gas that casts a shadow on the cosmic microwave background radiation. The shadow appears because the colder water absorbs the warmer microwave radiation on its path towards Earth, and its darkness reveals the temperature difference. As the temperature of the water can be determined from other observed properties of the starburst, the difference indicates the temperature of the Big Bang's relic radiation, which at that time was about seven times higher than in the Universe today.
'Besides proof of cooling, this discovery also shows us that the Universe in its infancy had some quite specific physical characteristics that no longer exist today,' said lead author Professor Dr Dominik Riechers from the University of Cologne's Institute of Astrophysics. 'Quite early, about 1.5 billion years after the Big Bang, the cosmic microwave background was already too cold for this effect to be observable. We have therefore a unique observing window that opens up to a very young Universe only,' he continued. In other words, if a galaxy with otherwise identical properties as HFLS3 were to exist today, the water shadow would not be observable because the required contrast in temperatures would no longer exist.
'This important milestone not only confirms the expected cooling trend for a much earlier epoch than has previously been possible to measure, but could also have direct implications for the nature of the elusive dark energy,' said co-author Dr Axel Weiss from the Max Planck Institute for Radio Astronomy (MPIfR) in Bonn. Dark energy is thought to be responsible for the accelerated expansion of the Universe over the past few billion years, but its properties remain poorly understood because it cannot be directly observed with the currently available facilities and instruments. However, its properties influence the evolution of cosmic expansion, and hence the cooling rate of the Universe over cosmic time. Based on this experiment, the properties of dark energy remain -- for now -- consistent with those of Einstein's 'cosmological constant'. 'That is to say, an expanding Universe in which the density of dark energy does not change,' explained Weiss.
Having discovered one such cold water cloud in a starburst galaxy in the early Universe, the team is now setting out to find many more across the sky. Their aim is to map out the cooling of the Big Bang echo within the first 1.5 billion years of cosmic history. 'This new technique provides important new insights into the evolution of the Universe, which are very difficult to constrain otherwise at such early epochs,' Riechers said.
'Our team is already following this up with NOEMA by studying the surroundings of other galaxies,' said co-author and NOEMA project scientist Dr Roberto Neri. 'With the expected improvements in precision from studies of larger samples of water clouds, it remains to be seen if our current, basic understanding of the expansion of the Universe holds.'
Dominik Riechers (University of Cologne) conducted the study together with his colleagues Axel Weiss (Max Planck Institute for Radio Astronomy, MPIfR), Fabian Walter (Max Planck Institute for Astronomy, MPIA), Christopher L. Carilli (National Radio Astronomy Observatory, NRAO), Pierre Cox (Institut d'Astrophysique de Paris, IAP, and Sorbonne Université), Roberto Decarli (INAF -- Osservatorio di Astrofisica e Scienza dello Spazio), and Roberto Neri (Institut de RadioAstronomie Millimétrique, IRAM).
The study was funded by the US National Science Foundation, the Alexander von Humboldt Foundation, the Max Planck Society, Institut National des Sciences de l'Univers/Centre National de la Recherche Scientifique, and Instituto Geográfico Nacional.

- ❖ Moons may yield clues to what makes planets habitable

Date: February 1, 2022
Source: University of Rochester



Earth and moon illustration (stock image).
Credit: © JohanSwanepoel / stock.adobe.com

Earth's moon is vitally important in making Earth the planet we know today: the moon controls the length of the day and ocean tides, which affect the biological cycles of lifeforms on our planet. The moon also contributes to

Earth's climate by stabilizing Earth's spin axis, offering an ideal environment for life to develop and evolve.
Because the moon is so important to life on Earth, scientists' conjecture that a moon may be a potentially beneficial feature in harbouring life on other planets. Most planets have moons, but Earth's moon is distinct in that it is large compared to the size of Earth; the moon's radius is larger than a quarter of Earth's radius, a much larger ratio than most moons to their planets.
Miki Nakajima, an assistant professor of earth and environmental sciences at the University of Rochester, finds that distinction significant. And in a new study that she led, published in *Nature Communications*, she and her colleagues at the Tokyo Institute of Technology and the University of Arizona examine moon formations and conclude that only certain types of planets can form moons that are large in respect to their host planets.
"By understanding moon formations, we have a better constraint on what to look for when searching for Earth-like planets," Nakajima says. "We expect that exomoons [moons orbiting planets outside our solar system] should be everywhere, but so far we haven't confirmed any. Our constraints will be helpful for future observations."

The origin of Earth's moon

Many scientists have historically believed Earth's large moon was generated by a collision between proto-Earth -- Earth at its early stages of development -- and a large, Mars-sized impactor, approximately 4.5 billion years ago. The collision resulted in the formation of a partially vaporized disk around Earth, which eventually formed into the moon.
In order to find out whether other planets can form similarly large moons, Nakajima and her colleagues conducted impact simulations on the computer, with a number of hypothetical Earth-like rocky planets and icy planets of varying masses. They hoped to identify whether the simulated impacts would result in partially vaporized disks, like the disk that formed Earth's moon.
The researchers found that rocky planets larger than six times the mass of Earth (6M) and icy planets larger than one Earth mass (1M) produce fully -- rather than partially -- vaporized disks, and these fully-vaporized disks are not capable of forming fractionally large moons.
"We found that if the planet is too massive, these impacts produce completely vapor disks because impacts between massive planets are generally more energetic than those between small planets," Nakajima says.
After an impact that results in a vaporized disk, over time, the disk cools and liquid moonlets -- a moon's building blocks -- emerge. In a fully-vaporized disk, the growing moonlets in the disk experience strong gas drag from vapor, falling onto the planet very quickly. In contrast, if the disk is only partially vaporized, moonlets do not feel such strong gas drag.
"As a result, we conclude that a completely vapor disk is not capable of forming fractionally large moons," Nakajima says. "Planetary masses need to be smaller than those thresholds we identified in order to produce such moons."

The search for Earth-like planets

The constraints outlined by Nakajima and her colleagues are important for astronomers investigating our universe; researchers have detected thousands of exoplanets and possible exomoons, but have yet to definitively spot a moon orbiting a planet outside our solar system.
This research may give them a better idea of where to look.
As Nakajima says: "The exoplanet search has typically been focused on planets larger than six earth masses. We are proposing that instead we should look at smaller planets because they are probably better candidates to host fractionally large moons."

- ❖ New Earth Trojan asteroid

Date: February 1, 2022
Source: University of Barcelona

An International team of astronomers led by researcher Toni Santana-Ros, from the University of Alicante and the Institute of Cosmos Sciences of the University of Barcelona (ICCUB), has confirmed the existence of the second Earth Trojan asteroid known to date, the 2020 XL_5, after a decade of search. The results of the study have been published in the journal *Nature Communications*.

All celestial objects that roam around our solar system feel the gravitational influence of all the other massive bodies that build it, including the Sun and the planets. If we consider only the Earth-Sun system, Newton's laws of gravity state that there are five points where all the forces that act upon an object located at that point cancel each other out. These regions are called LaGrange points, and they are areas of great stability. Earth Trojan asteroids are small bodies that orbit around the L_4 or L_5 LaGrange points of the Sun-Earth system.

These results confirm that 2020 XL_5 is the second transient Earth Trojan asteroid known to date, and everything indicates it will remain Trojan -- that is, it will be located at the LaGrange point -- for four thousand years, thus it is qualified as transient. The researchers have provided an estimation of the object bulk size (around one kilometre in diameter, larger than the Earth Trojan asteroid known to date, the 2010 TK_7, which was 0.3 kilometres in diameter), and have made a study of the impulse a rocket needs to reach the asteroid from Earth.

Although Trojan asteroids have been known to exist for decades in other planets such as Venus, Mars, Jupiter, Uranus and Neptune, it was not until 2011 that the first Earth Trojan asteroid was found. The astronomers have described many observational strategies for the detection of new Earth Trojans. "There have been many previous attempts to find Earth Trojans, including *in situ* surveys such as the search within the L_4 region, carried out by the NASA OSIRIS-Rex spacecraft, or the search within the L_5 region, conducted by the JAXA Hayabusa-2 mission," notes Toni Santana-Ros, author of the publication. He adds that "all the dedicated efforts had so far failed to discover any new member of this population."

The low success in these searches can be explained by the geometry of an object orbiting the Earth-Sun L_4 or L_5 as seen from our planet. These objects are usually observable close to the sun. The observation time window between the asteroid rising above the horizon and sunrise is, therefore, very small. Therefore, astronomers point their telescopes very low on the sky where the visibility conditions are at their worst and with the handicap of the imminent sunlight saturating the background light of the images just a few minutes in the observation.

To solve this problem, the team carried out a search of 4-meter telescopes that would be able to observe under such conditions, and they finally obtained the data from the 4.3m Lowel Discovery telescope (Arizona, United States), and the 4.1m SOAR telescope, operated by the National Science Foundation NOIRLab (Cerro Pachón, Chile).

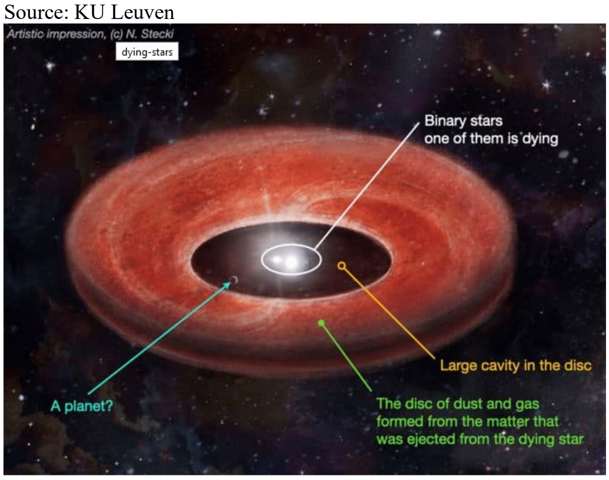
The discovery of the Earth Trojan asteroids is very significant because these can hold a pristine record on the early conditions in the formation of the Solar System, since the primitive trojans might have been co-orbiting the planets during their formation, and they add restrictions to the dynamic evolution of the Solar System. In addition, Earth Trojans are the ideal candidates for potential space missions in the future.

Since the L_4 LaGrange point shares the same orbit as the Earth, it takes a low change in velocity to be reached. This implies that a spacecraft would need a low energy budget to remain in its shared orbit with the Earth, keeping a fixed distance to it. "Earth Trojans could become ideal bases for an advanced exploration of the Solar System; they could even become a source of resources," concludes Santana-Ros.

The discovery of more trojans will enhance our knowledge of the dynamics of these unknown objects and will provide a better understanding of the mechanics that allow them to be transient.

- Even dying stars can still give birth to planets

Date: February 1, 2022
Source: KU Leuven



Discs surrounding so-called evolved binary stars not uncommonly show signs that could point to planet formation. CREDIT © N. Stecki

Planets are usually not much older than the stars around which they revolve. Take the Sun: it was born 4.6 billion years ago, and not long after that, Earth came into the world. But KU Leuven astronomers have discovered that a completely different scenario is also possible. Even if they are near death, some types of stars can possibly still form planets. If this is confirmed, theories on planet formation will need to be adjusted.

Planets such as Earth, and all other planets in our solar system, were formed not long after the Sun. Our Sun started to burn 4.6 billion years ago, and in the next million years, the matter around it clumped into protoplanets. The birth of the planets in that protoplanetary disc, a gigantic pancake made of dust and gas, so to speak, with the Sun in the middle, explains why they all orbit in the same plane. But such discs of dust and gas needn't necessarily only surround new-born stars. They can also develop independently from star formation, for example around binary stars of which one is dying (binary stars are two stars that orbit each other, also called a binary system). When the end approaches for a medium-sized star (like the Sun), it catapults the outer part of its atmosphere into space, after which it slowly dies out as a so-called white dwarf. However, in the case of binary stars, the gravitational pull of the second star causes the matter ejected by the dying star to form a flat, rotating disc. Moreover, this disc strongly resembles the protoplanetary discs that astronomers observe around young stars elsewhere in the Milky Way.

This we already knew. However, what is new is that the discs surrounding so-called evolved binary stars not uncommonly show signs that could point to planet formation, as discovered by an international team of astronomers led by KU Leuven researchers. What's more, their observations show that this is the case for one in ten of these binary stars. "In ten per cent of the evolved binary stars with discs we studied, we see a large cavity (a void/opening, ed.) in the disc," says KU Leuven astronomer Jacques Kluska, first author of the article in the journal *Astronomy & Astrophysics* in which the discovery is described. "This is an indication that something is floating around there that has collected all matter in the area of the cavity."

Second-generation planets

The clean-up of the matter could be the work of a planet. That planet might not have formed at the very beginning of one of the binary stars' life, but at the very end. The astronomers moreover found further strong indications for the presence of such planets. "In the evolved binary stars with a large cavity in the disc, we saw those heavy elements such as iron were very scarce on the surface of the dying star," says Kluska. "This observation leads one to suspect that dust particles rich in these elements were trapped by a planet." By the way, the Leuven astronomer doesn't rule out the possibility that in this way, several planets can be formed around these binary stars.

The discovery was made when the astronomers were drawing up an inventory of evolved binary stars in our Milky Way. They did that based on existing, publicly available observations. Kluska and his colleagues counted 85 of such binary star pairs. In ten pairs, the researchers came across a disc with a large cavity on the infrared images.

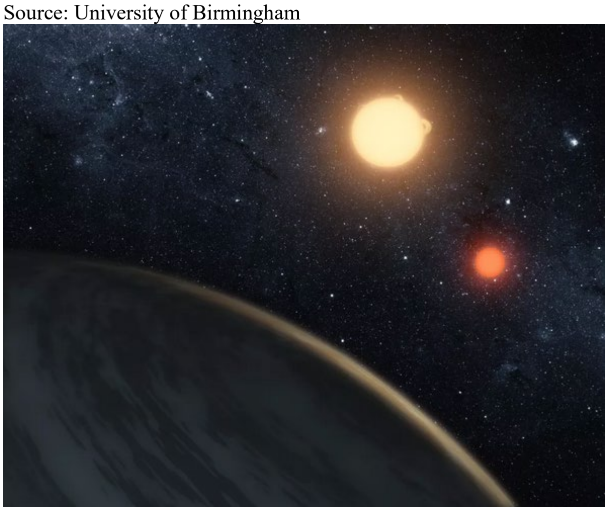
Current theories put to the test

If new observations confirm the existence of planets around evolved binary stars, and if it turns out the planets were only formed after one of the stars had reached the end of its life, the theories on planet formation will need to be adjusted. "The confirmation or refutation of this extraordinary way of planet formation will be an unprecedented test for the current theories," according to Professor Hans Van Winckel, head of the KU Leuven Institute of Astronomy.

The KU Leuven astronomers soon want to verify their hypothesis themselves. To this end, they will use the big telescopes of the European Southern Observatory in Chile to take a closer look at the ten pairs of binary stars whose discs show a large cavity.

- ❖ 'Tatooine-like' exoplanet spotted by ground-based telescope

Date: February 23, 2022
Source: University of Birmingham



Kepler-16b, seen in this artist's impression, orbits two stars and has double sunsets, just like Tatooine in Star Wars. (Image credit: Tim Pyle/NASA/JPL-Caltech)

A rare exoplanet which orbits around two stars at once has been detected using a ground-based telescope by a team led by the University of Birmingham.

The planet, called Kepler-16b, has so far only been seen using the Kepler space telescope. It orbits around two stars, with the two orbits also orbiting one another, forming a binary star system. Kepler-16b is located some 245 light years from Earth and, like Luke Skywalker's home planet of Tatooine, in the Star Wars universe, it would have two sunsets if you could stand on its surface.

The 193cm telescope used in the new observation is based at the Observatoire de Haute-Provence, in France. The team were able to detect the planet using the radial velocity method, in which astronomers observe a change in the velocity of a star as a planet orbits about it.

The detection of Kepler-16b using the radial velocity method is an important demonstration that it is possible to detect circumbinary planets using more traditional methods, at greater efficiency and lower cost than by using spacecrafts.

Importantly the radial velocity method is also more sensitive to additional planets in a system, and it can also measure the mass of a planet -- its most fundamental property.

Having demonstrated the method using Kepler-16b, the team plans to continue the search for previously unknown circumbinary planets and help answer questions about how planets are formed. Usually, planets formation is thought to take place within a protoplanetary disc -- a mass of dust and gas which surrounds a young star. However, this process may not be possible within a circumbinary system.

Professor Amaury Triaud, from the University of Birmingham, who led the team, explains: "Using this standard explanation it is difficult to understand how circumbinary planets can exist. That's because the presence of two stars interferes with the protoplanetary disc, and this prevents dust from agglomerating into planets, a process called accretion.

"The planet may have formed far from the two stars, where their influence is weaker, and then moved inwards in a process called disc-driven migration -- or, alternatively, we may find we need to revise our understanding of the process of planetary accretion."

Dr David Martin, from the Ohio State University (USA), who contributed to the discovery, explains "Circumbinary planets provide one of the clearest clues that disc-driven migration is a viable process, and that it happens regularly."

Dr Alexandre Santerne, from the University of Marseille, a collaborator on the research explains: "Kepler-16b was first discovered 10 years ago by NASA's *Kepler* satellite using *the transit method*. This system was the most unexpected discovery made by *Kepler*. We chose to turn our telescope and recover Kepler-16 to demonstrate the validity of our radial-velocity methods."

Dr Isabelle Boisse, also from the University of Marseille, is the scientist in charge of the SOPHIE instrument that was used to collect the data. She said: "Our discovery shows how ground-based telescopes remain entirely relevant to modern exoplanet research and can be used for exciting new projects. Having shown we can detect Kepler-16b, we will now analyse data taken on many other binary star systems, and search for new circumbinary planets."

- ❖ What ingredients went into the galactic blender to create the Milky Way?

Our galaxy is a giant 'smoothie' of blended stars and gas but a new study tells us where the components came from

Date: February 22, 2022

Source: ARC Centre of Excellence for All Sky Astrophysics in 3D (ASTRO 3D)

In its early days, the Milky Way was like a giant smoothie, as if galaxies consisting of billions of stars, and an enormous amount of gas had been thrown together into a gigantic blender. But a new study picks apart this mixture by analysing individual stars to identify which originated inside the galaxy and which began life outside.

"Although the Milky Way is our home galaxy, we still do not understand how it formed and evolved," says researcher Sven Buder from the

ARC Centre of Excellence for All Sky Astrophysics in 3 Dimensions (ASTRO 3D) and the Australian National University (ANU).
His paper, published this week in the *Monthly Notices of the Royal Astronomical Society*, analyses the light from stars in detail, helping to understand what elements went into the creation of the Milky Way we know today.
"The Milky Way ate up lots of smaller galaxies but, until recently, we did not have enough evidence of that to say for sure," Buder says. "That's because simple images of stars in our Milky Way look the same -- whether they were born inside the galaxy or outside and then blended into the galaxy."
Buder and colleagues in the Galactic Archaeology with HERMES (GALAH) team used Australia's largest optical telescope, the Anglo-Australian Telescope (AAT), at Siding Spring Observatory to split light from more than 600,000 stars into wavelengths with the HERMES (High Efficiency and Resolution Multi-Element Spectrograph) instrument. This effectively creates 600,000 stellar rainbows known as spectra. Within each of these rainbows are specific bands of light -- rather like tiny unique barcodes -- that vary depending on a star's chemical composition.
"If an image is worth a thousand words, these spectra are worth more than a thousand pictures," says Buder. "By 'scanning' these stellar barcodes, we measured how abundant 30 elements, such as sodium, iron, magnesium, and manganese, were, and how they appeared in different concentrations depending on where the star was born."
This discovery is an early step towards reconstructing a picture of the "childhood" of the Milky Way to get an idea of the size of the galaxies that it consumed in the process. "It could also help us understand how several of the features of the galaxy we know today came into being," says Buder.
One mystery the new observations could help solved is why there are two distinct groups of stars in the disc that we see as the "milky" band in the night sky.
"The Milky Way spread out across the night sky is a familiar sight, and when we look at it, we are actually gazing into the centre of our galaxy with its billions of stars," says Buder. "But we are looking at two populations of stars, one much older than the other. The old stars have moved so they look like they bulge out of the main plane of the Milky Way, while the younger stars form a much thinner band in the plane. "But we don't know why this has happened and our latest findings of the remnants of gigantic, galactic collisions may help us understand," says Buder.
Buder's paper provides the latest revelations relying on data from the Gaia project -- an ambitious satellite mission to chart a three-dimensional map of the Milky Way to help understand its orbits, composition, formation, and evolution. The Gaia satellite measurements can help us to find candidates of previously extragalactic stars, because they still move differently from a typical Milky Way star. But the extragalactic origin of a star can only be confirmed by its chemical fingerprint.