South Downs Mercury

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Main Talk William Joyce completes and expands on his talk of last February on the "
Scientific Exploration of the Moon
Several phases of lunar exploration have taken place over the last century, and a new phase is imminent. This discussion presents some highlights and key events which informed our current knowledge of the Moon, recent scientific results and how these have influenced our understanding of lunar origin and evolution, and a glimpse of what the near future may hold. A variety of lunar features are described along with geological exploration of the surface from Apollo landings and by remote sensing from orbit, presenting a modern summary of current lunar science.
With an astrophysics degree, William has worked in space research at Leicester university with Earth remote sensing satellite instruments and in industry in laboratories, space software engineering and later in aerospace systems engineering. William changed career in the mid 2000's and obtained a degree in Earth and Planetary science and followed this with university teaching and astronomy work (and teaching at Herstmonceux observatory). Currently he is studying for a PhD and gives public talks on astronomy and planetary science

Please support a raffle we are organizing this month.

- Birth of universe's earliest galaxies observed for first time

Date: May 23, 2024
Source: University of Copenhagen - Faculty of Science

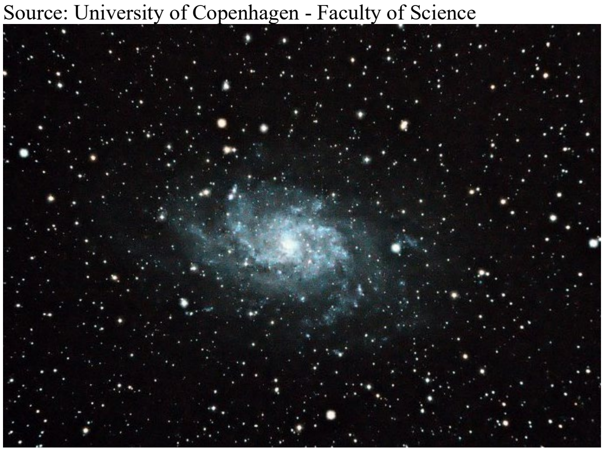

image: :@Ludovic Debono | iStock

Using the James Webb Space Telescope, University of Copenhagen researchers have become the first to see the formation of three of the earliest galaxies in the universe, more than 13 billion years ago. The sensational discovery contributes important knowledge about the universe and is now published in the journal *Science*.
For the first time in the history of astronomy, researchers at the Niels Bohr Institute have witnessed the birth of three of the universe's absolute earliest galaxies, somewhere between 13.3 and 13.4 billion years ago.

The discovery was made using the James Webb Space Telescope, which brought these first 'live observations' of formative galaxies down to us here on Earth.
Through the telescope, researchers were able to see signals from large amounts of gas that accumulate and accrete onto a mini-galaxy in the process of being built. While this is how galaxies are formed according to theories and computer simulations, it had never actually been witnessed.
"You could say that these are the first 'direct' images of galaxy formation that we've ever seen. Whereas the James Webb has previously shown us early galaxies at later stages of evolution, here we witness their very birth, and thus, the construction of the first star systems in the universe," says Assistant Professor Kasper Elm Heintz from the Niels Bohr Institute, who led the new study.

Galaxies born shortly after the Big Bang

The researchers estimate the birth of the three galaxies to have occurred roughly 400-600 million years after the Big Bang, the explosion that began it all. While that sounds like a long time, it corresponds to galaxies forming during the first three to four percent of the universe's 13.8-billion-year overall lifetime.
Shortly after the Big Bang, the universe was an enormous opaque gas of hydrogen atoms --

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unlike today, where the night sky is speckled with a blanket of well-defined stars.

"During the few hundred million years after the Big Bang, the first stars formed, before stars and gas began to coalesce into galaxies. This is the process that we see the beginning of in our observations," explains Associate Professor Darach Watson.

The birth of galaxies took place at a time in the history of the universe known as the Epoch of Reionization, when the energy and light of some of the first galaxies broke through the mists of hydrogen gas.

It is precisely these large amounts of hydrogen gas that the researchers captured using the James Webb Space Telescope's infrared vision. This is the most distant measurement of the cold, neutral hydrogen gas, which is the building block of the stars and galaxies, discovered by scientific researchers to date.

Adds to the understanding of our origins

The study was conducted by Kasper Elm Heintz, in close collaboration with, among others, research colleagues Darach Watson, Gabriel Brammer and PhD student Simone Vejlgaard from the Cosmic Dawn Centre at the University of Copenhagen's Niels Bohr Institute -- a centre whose stated goal is to investigate and understand the dawn of the universe. This latest result brings them much closer to doing just that.

The research team has already applied for more observation time with the James Webb Space Telescope, with hopes of expanding upon their new result and learning more about the earliest epoch in the formation of galaxies.

"For now, this is about mapping our new observations of galaxies being formed in even greater detail than before. At the same time, we are constantly trying to push the limit of how far out into the universe we can see. So, perhaps we'll reach even further," says Simone Vejlgaard.

According to the researcher, the new knowledge contributes to answering one of humanity's most basic questions.

"One of the most fundamental questions that we humans have always asked is: 'Where do we come from?'. Here, we piece together a bit more of the answer by shedding light on the moment that some of the universe's first structures were created. It is a process that we'll investigate further, until hopefully, we are able to fit even more pieces of the puzzle together," concludes Associate Professor Gabriel Brammer.

The study was conducted by researchers Kasper E. Heintz, Darach Watson, Gabriel Brammer, Simone Vejlgaard, Anne Hutter, Victoria B. Strait, Jorryt Matthee, Pascal A. Oesch, Pall Jakobsson, Nial R. Tanvir, Peter Laursen, Rohan P. Naidu, Charlotte A. Mason, Meghana Killi, Intae Jung, Tiger Yu-Yang Hsiao, Abdurro'uf, Dan Coe, Pablo Arrabal Haro, Steven L. Finkelstein, & Sune Toft.

The Danish portion of the research is funded by the Danish National Research Foundation and the Carlsberg Foundation.

HOW THEY DID IT

Researchers were able to measure the formation of the universe's first galaxies by using sophisticated models of how light from these galaxies was absorbed by the neutral gas located in and around them. This transition is known as the Lyman-alpha transition.

By measuring the light, the researchers were able to distinguish gas from the newly formed galaxies from other gas. These measurements were only possible thanks to the James Webb Space Telescope's incredibly sensitive infrared spectrograph capabilities.

ABOUT THE EARLY UNIVERSE

The universe began its "life" about 13.8 billion years ago in an enormous explosion -- the Big Bang. The event gave rise to an abundance of subatomic particles such as quarks and electrons. These particles aggregated to form protons and neutrons, which later coalesced into atomic nuclei. Roughly 380,000 years after the Big Bang, electrons began to orbit atomic nuclei, and the simplest atoms of the universe gradually formed.

The first stars were formed after a few hundred million years. And within the hearts of these stars, the larger and more complex atoms that we have around us were formed. Later, stars coalesced into galaxies. The oldest galaxies known to us were formed about 3-400 million years after the Big Bang. Our own solar system came into being about 4.6 billion years ago -- more than 9 billion years after the Big Bang.

- ❖ First pictures from Euclid satellite reveal billions of orphan stars

Date: May 23, 2024
Source: University of Nottingham

Captured by the Euclid satellite. Depicts the Perseus cluster of galaxies bathed in a gentle, soft blue light emanating from orphan stars. These orphan stars are dispersed throughout the cluster, extending up to 2 million light-years from its centre. The cluster galaxies stand out as luminous elliptical shapes against the dark expanse of space. Image Credit: ESA/Euclid/Euclid Consortium/NASA, image processing by M. Montes (IAC) and J.-C. Cuillandre (CEA Paris-Saclay)

The first scientific pictures from the Euclid satellite mission have revealed more than 1,500 billion orphan stars scattered throughout the Perseus cluster of galaxies. Led by astronomers from the University of Nottingham, this discovery sheds light on the origins of these celestial wanderers.

The Perseus cluster, located 240 million light-years away from Earth, is one of the Universe's most massive structures, boasting thousands of galaxies. However, amidst this cosmic ensemble, the Euclid satellite captured faint ghostly light -- the orphan stars -- drifting between the cluster's galaxies.

Stars naturally form within galaxies, so the presence of orphan stars outside these structures raised intriguing questions about their origins.

Professor Nina Hatch, who led the project team, said, "We were surprised by our ability to see so far into the outer regions of the cluster and discern the subtle colours of this light. This light can help us map dark matter if we understand where the intracluster stars came from. By studying their colours, luminosity, and configurations, we found they originated from small galaxies."

The orphan stars are characterised by their bluish hue and clustered arrangement. Based on these distinctive features the astronomers involved in the study suggest that the stars were torn from the outskirts of galaxies and from the complete disruption of smaller cluster galaxies, known as dwarfs.

After being torn from their parent galaxies, the orphaned stars were expected to orbit around the largest galaxy within the cluster. However, this study revealed a surprising finding: the orphan stars instead circled a point between the two most luminous galaxies in the cluster.

Dr Jesse Golden-Marx, a Nottingham astronomer involved in the study, commented, "This novel observation suggests that the massive Perseus cluster may have recently undergone a merger with another group of galaxies. This recent merger could have induced a gravitational disturbance, causing either the most massive galaxy or the orphan stars to deviate from their expected orbits, thus resulting in the observed misalignment."

Dr Matthias Kluge, first author on the study, from the Max-Planck institute for Extraterrestrial Physics in Munich, Germany, stated: "This diffuse light is more than 100,000 times fainter than the darkest night sky on Earth. But it is spread over such a large volume that when we add it all up, it accounts for about 20% of the luminosity of the entire cluster."

ESA's Euclid mission is designed to explore the composition and evolution of the dark Universe. The space telescope will create a great map of the large-scale structure of the Universe across space and time by observing billions of galaxies out to 10 billion light-years, across more than a third of the sky. Euclid will explore how the Universe has expanded and how structure has formed over cosmic history, revealing more about the role of gravity and the nature of dark energy and dark matter.

Dr Mireia Montes, an astronomer from the Institute of Astrophysics on the Canary Islands involved in the study said, "This work was only possible thanks to Euclid's sensitivity and sharpness." Euclid's revolutionary design means that it can take images with similar sharpness as the Hubble Space Telescope, but covering an area that is 175 times larger.

- ❖ Planet hunters unveil massive catalogue of strange worlds

Mass, density of 126 planets described

Date: May 23, 2024
Source: University of California – Riverside

While thousands of planets have been discovered around other stars, relatively little is known about them. A NASA catalogue featuring 126 exotic, newly discovered worlds include detailed measurements that allow for comparisons with our own solar system.
The catalogue details a fascinating mix of planet types beyond our solar system, from rare worlds with extreme environments to ones that could possibly support life.
The planets were analysed by a large, international team of scientists using NASA's Transiting Exoplanet Survey Satellite (TESS) in collaboration with the W.M. Keck Observatory on Maunakea, Hawai'i. They are described in today's edition of *The Astrophysical Journal Supplement*.
"Relatively few of the previously known exoplanets have a measurement of both the mass and the radius. The combination of these measurements tells us what the planets could be made of and how they formed," said Stephen Kane, UC Riverside astrophysicist and principal investigator of the TESS-Keck Survey.
"With this information, we can begin to answer questions about where our solar system fits in to the grand tapestry of other planetary systems," Kane said.
The research team spent three years developing the catalogue. They analysed more than 13,000 radial velocity (RV) measurements to calculate the masses of 120 confirmed planets, plus six candidate planets, spread out over the northern sky.
Though the planets themselves aren't visible, they do have a visible effect. As they orbit, the planets tug on their host stars, causing them to "wobble." When the star moves toward a telescope, its visible light turns slightly bluer; when it moves away from us, the light shifts slightly redder.
This is much like how sound behaves. Due to the Doppler effect, a fire truck's siren gets higher-pitched as it travels closer and sounds lower-pitched as it drives farther away.
"These RV measurements let astronomers detect and learn the properties of these exoplanetary systems. When we see a star wobbling regularly back and forth, we can infer the presence of an orbiting planet and measure the planet's mass," said Ian Crossfield, University of Kansas astrophysicist and catalogue co-author.
Several planets in the TESS-Keck Survey stand out as touchstones for deepening astronomers' understanding of the diverse ways planets form and evolve.
A related survey paper authored by UCR graduate student Michelle Hill announces the discovery of two new planets orbiting a star like our sun. The first is a "sub-Saturn" planet with a mass and radius that are between those of Neptune and Saturn.
"There is ongoing debate about whether sub-Saturn planets are truly rare, or if we are just bad at finding planets like these," Hill said. "So, this planet, TOI-1386 b, is an important addition to this demographic of planets."
TOI-1386 b only takes 26 days to orbit its star. Meanwhile its neighbour, a planet with a mass close to that of Saturn, takes 227-days to orbit the same star.
Another survey paper authored by UCR graduate student Daria Pidhorodetska describes a planet about half the size of Neptune that takes a mere 19 days to orbit its star, which is much like our Sun.
"Planets smaller than Neptune but larger than Earth are the most prevalent worlds in our galaxy, yet they are absent from our own Solar System. Each time a new one is discovered, we are reminded of how diverse our Universe is, and that our existence in the cosmos may be more unique than we can understand," Pidhorodetska said.
There are a lot of stars that are not similar to our sun. If scientists want to make apt comparisons between our world and others, they need to find stars of a similar age, size, and mass. "Then we can do apples-to-apples comparisons," Kane said. "That's the exciting part of the papers produced by Michelle and Daria, because they allow for this."
Planets with even more extreme, ultra-short orbits around stars unlike our sun are also

detailed in the catalogue. One is so close to its orange dwarf star it completes orbit in less than 12 hours.

"TOI-1798 c orbits its star so quickly that one year on this planet lasts less than half a day on Earth. Because of their proximity to their host stars, planets like this one are also ultra hot -- receiving more than 3,000 times the radiation that Earth receives from the sun," said Alex Polanski, University of Kansas physics and astronomy graduate student and lead author of the catalogue paper.

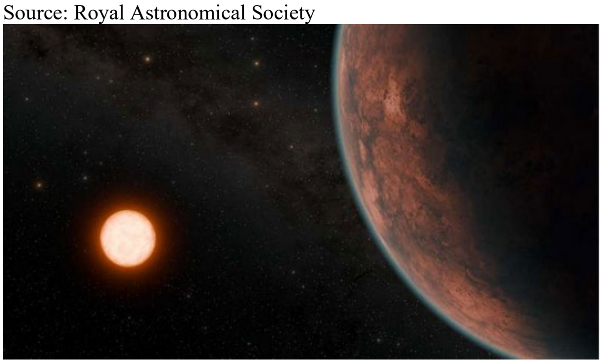
"Existing in this extreme environment means that this planet has likely lost any atmosphere that it initially formed," Polanski said.

Ultimately, this new catalogue represents a major contribution both to NASA's TESS mission, and toward answering the question of whether other planets are capable of hosting life as we know it.

"Are we unusual? The jury is still out on that one, but our new mass catalogue represents a major step toward answering that question," Kane said.

- Potentially habitable 'exo-Venus' with Earth-like temperature discovered

Date: May 23, 2024
Source: Royal Astronomical Society



Gliese 12 b, which orbits a cool, red dwarf star located just 40 light-years away, promises to tell astronomers more about how planets close to their stars retain or lose their atmospheres. In this artist's concept, Gliese 12 b is shown retaining a thin atmosphere. Credit: NASA/JPL-Caltech/R. Hurt (Caltech-IPAC)

Astronomers have made the rare and tantalising discovery of an Earth-like exoplanet 40 light-years away that may be just a little warmer than our own world.

The potentially-habitable planet, named Gliese 12 b, orbits its host star every 12.8 days, is comparable in size to Venus -- so slightly smaller than Earth -- and has an estimated surface temperature of 42°C (107°F), which is lower than most of the 5,000-odd exoplanets confirmed so far.

That is assuming it has no atmosphere, however, which is the crucial next step to establishing if it is habitable.

It may have an Earth-like atmosphere, one more akin to Venus -- which experienced a runaway greenhouse effect that made it a 400°C (752°F) hellhole -- no atmosphere, or perhaps a different kind of atmosphere not found in our solar system.

Getting an answer is vital because it would reveal if Gliese 12 b can maintain temperatures suitable for liquid water -- and possibly life -- to exist on its surface, while also unlocking answers about how and why Earth and Venus evolved so differently.

Gliese 12 b is by no means the first Earth-like exoplanet to have been discovered, but as NASA has said, there are only a handful of worlds like it that warrant a closer look.

It has been billed as "the nearest, transiting, temperate, Earth-size world located to date" and a potential target for further investigation by the US space agency's £7.5billion James Webb Space Telescope.

The closest Earth-like exoplanet to us -- and possibly the most famous -- is Proxima Centauri b, which is only 4 light-years away. However, because it is not a transiting world we still have a lot to learn about it, including whether it has an atmosphere and the potential to harbour life.

Most exoplanets are discovered using the transit method, where a planet passes in front of its star from our point of view, causing a dip in the host star's brightness.

During a transit, the star's light also passes through an exoplanet's atmosphere and some wavelengths get absorbed. Different gas molecules absorb different colours, so the transit provides a set of chemical fingerprints that can be detected by telescopes like Webb.

Gliese 12 b could also be significant because it may help reveal whether the majority of stars in our Milky Way galaxy -- i.e. cool stars -- are capable of hosting temperate planets that have atmospheres and are therefore habitable.

The discovery of the 'exo-Venus', by two international teams of astronomers, has been published today in the *Monthly Notices of the Royal Astronomical Society*.

It orbits a cool red dwarf star called Gliese 12, which is almost 40 light-years away from Earth in the constellation Pisces.

"Gliese 12 b represents one of the best targets to study whether Earth-size planets orbiting cool stars can retain their atmospheres, a crucial step to advance our understanding of habitability on planets across our galaxy," said

Shishir Dholakia, a doctoral student at the Centre for Astrophysics at the University of Southern Queensland in Australia.
He co-led a research team with Larissa Palethorpe, a doctoral student at the University of Edinburgh and University College London.
The exoplanet's host star is about 27 per cent of the size of our Sun and has a surface temperature that is around 60 per cent of our own star.
However, the distance separating Gliese 12 and the new planet is just 7 per cent of the distance between Earth and the Sun. Gliese 12 b therefore receives 1.6 times more energy from its star as Earth does from the Sun and about 85 per cent of what Venus experiences.
This difference in solar radiation is important because it means the planet's surface temperature is highly dependent on its atmospheric conditions. As a comparison to Gliese 12 b's estimated surface temperature of 42°C (107°F), Earth has an average surface temperature of 15°C (59°F).
"Atmospheres trap heat and -- depending on the type -- can change the actual surface temperature substantially," Dholakia explained. "We are quoting the planet's 'equilibrium temperature', which is the temperature the planet would be if it had no atmosphere.
"Much of the scientific value of this planet is to understand what kind of atmosphere it could have. Since Gliese 12 b gets in between the amount of light as Earth and Venus get from the Sun, it will be valuable for bridging the gap between these two planets in our solar system."
Palethorpe added: "It is thought that Earth's and Venus's first atmospheres were stripped away and then replenished by volcanic outgassing and bombardments from residual material in the solar system.
"The Earth is habitable, but Venus is not due to its complete loss of water. Because Gliese 12 b is between Earth and Venus in temperature, its atmosphere could teach us a lot about the habitability pathways planets take as they develop."
The researchers, along with another team in Tokyo, used observations by NASA's TESS (Transiting Exoplanet Survey Satellite) to help make their discovery.
"We've found the nearest, transiting, temperate, Earth-size world located to date," said Masayuki Kuzuhara, a project assistant professor at the Astrobiology Centre in Tokyo, who co-led a research team with Akihiko Fukui, a project assistant professor at the University of Tokyo.
"Although we don't yet know whether it possesses an atmosphere, we've been thinking of it as an exo-Venus, with similar size and energy received from its star as our planetary neighbour in the solar system."
An important factor in retaining an atmosphere is the storminess of its star. Red dwarfs tend to be magnetically active, resulting in frequent, powerful X-ray flares. However, analyses by both teams conclude that Gliese 12 shows no signs of such extreme behaviour, raising hopes that Gliese 12 b's atmosphere may still be intact.
"We know of only a handful of temperate planets similar to Earth that are both close enough to us and meet other criteria needed for this kind of study, called transmission spectroscopy, using current facilities," said Michael McElwain, a research astrophysicist at NASA's Goddard Space Flight Centre in Greenbelt, Maryland, and a co-author of the Kuzuhara and Fukui paper.
"To better understand the diversity of atmospheres and evolutionary outcomes for these planets, we need more examples like Gliese 12 b."
At 40 light-years from Earth, Gliese 12 b is about the same distance as the TRAPPIST-1 system.
This is made up of seven planets, all roughly in Earth's size range and likely rocky, orbiting a red dwarf star.
Three of these are in the habitable zone but at least two -- and probably all of them -- have no atmosphere and are likely barren, dismissing hopes when they were first discovered eight years ago that they could be water worlds hosting life.

- ❖ Intriguing nearby world sized between Earth, Venus

Date: May 23, 2024
Source: NASA/Goddard Space Flight Centre

Gliese 12 b's estimated size may be as large as Earth or slightly smaller—comparable to Venus in our solar system. This artist's concept compares Earth with different possible Gliese 12 b interpretations, from one with no atmosphere to one with a thick Venus-like one. Follow-up observations with NASA's James Webb Space Telescope could help determine just how much atmosphere the planet retains as well as its composition. Credit: NASA/JPL-Caltech/R. Hurt (Caltech-IPAC)

Using observations by NASA's TESS (Transiting Exoplanet Survey Satellite) and many other facilities, two international teams of astronomers have discovered a planet between the sizes of Earth and Venus only 40 light-years away. Multiple factors make it a candidate well-suited for further study using NASA's James Webb Space Telescope.

TESS stares at a large swath of the sky for about a month at a time, tracking the brightness changes of tens of thousands of stars at intervals ranging from 20 seconds to 30 minutes. Capturing transits -- brief, regular dimming of stars caused by the passage of orbiting worlds -- is one of the mission's primary goals.

"We've found the nearest, transiting, temperate, Earth-size world located to date," said Masayuki Kuzuhara, a project assistant professor at the Astrobiology Centre in Tokyo, who co-led one research team with Akihiko Fukui, a project assistant professor at the University of Tokyo. "Although we don't yet know whether it possesses an atmosphere, we've been thinking of it as an exo-Venus, with similar size and energy received from its star as our planetary neighbour in the solar system."

The host star, called Gliese 12, is a cool red dwarf located almost 40 light-years away in the constellation Pisces. The star is only about 27% of the Sun's size, with about 60% of the Sun's surface temperature. The newly discovered world, named Gliese 12 b, orbits every 12.8 days and is Earth's size or slightly smaller -- comparable to Venus. Assuming it has no atmosphere, the planet has a surface temperature estimated at around 107 degrees Fahrenheit (42 degrees Celsius).

Astronomers say that the diminutive sizes and masses of red dwarf stars make them ideal for finding Earth-size planets. A smaller star means greater dimming for each transit, and a lower mass means an orbiting planet can produce a greater wobble, known as "reflex motion," of the star. These effects make smaller planets easier to detect.

The lower luminosities of red dwarf stars also means their habitable zones -- the range of orbital distances where liquid water could exist on a planet's surface -- lie closer to them. This makes it easier to detect transiting planets within habitable zones around red dwarfs than those around stars emitting more energy.

The distance separating Gliese 12 and the new planet is just 7% of the distance between Earth and the Sun. The planet receives 1.6 times more energy from its star as Earth does from the Sun and about 85% of what Venus experiences.

"Gliese 12 b represents one of the best targets to study whether Earth-size planets orbiting cool stars can retain their atmospheres, a crucial step to advance our understanding of habitability on planets across our galaxy," said Shishir Dholakia, a doctoral student at the Centre for Astrophysics at the University of Southern Queensland in Australia. He co-led a different research team with Larissa Palethorpe, a doctoral student at the University of Edinburgh and University College London.

Both teams suggest that studying Gliese 12 b may help unlock some aspects of our own solar system's evolution.

"It is thought that Earth's and Venus's first atmospheres were stripped away and then replenished by volcanic outgassing and bombardments from residual material in the solar system," Palethorpe explained. "The Earth is habitable, but Venus is not due to its complete loss of water. Because Gliese 12 b is between Earth and Venus in temperature, its atmosphere could teach us a lot about the habitability pathways planets take as they develop."

One important factor in retaining an atmosphere is the storminess of its star. Red dwarfs tend to be magnetically active, resulting in frequent, powerful X-ray flares. However, analyses by both teams conclude that Gliese 12 shows no signs of extreme behaviour.

A paper led by Kuzuhara and Fukui was published May 23 in The Astrophysical Journal Letters. The Dholakia and Palethorpe findings were published in Monthly Notices of the Royal Astronomical Society on the same day.

During a transit, the host star's light passes through any atmosphere. Different gas molecules absorb different colours, so the transit provides a set of chemical fingerprints that can be detected by telescopes like Webb.

"We know of only a handful of temperate planets similar to Earth that are both close enough to us and meet other criteria needed for this kind of study, called transmission spectroscopy, using current facilities," said Michael McElwain, a research astrophysicist at NASA's Goddard Space Flight Centre in Greenbelt, Maryland, and a co-author of the Kuzuhara and Fukui paper. "To better understand the diversity of atmospheres and evolutionary outcomes for these planets, we need more examples like Gliese 12 b."

- ❖ The origin of the sun's magnetic field could lie close to its surface

Sunspots and flares could be a product of a shallow magnetic field, according to surprising new findings that may help scientists predict space weather

Date: May 22, 2024
Source: Massachusetts Institute of Technology

The sun's surface is a brilliant display of sunspots and flares driven by the solar magnetic field, which is internally generated through a process called dynamo action.

Astrophysicists have assumed that the sun's field is generated deep within the star. But an MIT study finds that the sun's activity may be shaped by a much shallower process.

In a paper appearing in *Nature*, researchers at MIT, the University of Edinburgh, and elsewhere find that the sun's magnetic field could arise from instabilities within the sun's outermost layers.

The team generated a precise model of the sun's surface and found that when they simulated certain perturbations, or changes in the flow of plasma (ionized gas) within the top 5 to 10 percent of the sun, these surface changes were enough to generate realistic magnetic field patterns, with similar characteristics to what astronomers have observed on the sun. In contrast, their simulations in deeper layers produced less realistic solar activity.

The findings suggest that sunspots and flares could be a product of a shallow magnetic field, rather than a field that originates deeper in the sun, as scientists had largely assumed.

"The features we see when looking at the sun, like the corona that many people saw during the recent solar eclipse, sunspots, and solar flares, are all associated with the sun's magnetic field," says study author Keaton Burns, a research scientist in MIT's Department of Mathematics. "We show that isolated perturbations near the sun's surface, far from the deeper layers, can grow over time to potentially produce the magnetic structures we see."

If the sun's magnetic field does in fact arise from its outermost layers, this might give scientists a better chance at forecasting flares and geomagnetic storms that have the potential to damage satellites and telecommunications systems.

"We know the dynamo acts like a giant clock with many complex interacting parts," says co-author Geoffrey Vasil, a researcher at the University of Edinburgh. "But we don't know many of the pieces or how they fit together. This new idea of how the solar dynamo starts is essential to understanding and predicting it."

The study's co-authors also include Daniel Lecoanet and Kyle Augustson of Northwestern University, Jeffrey Oishi of Bates College, Benjamin Brown and Keith Julien of the University of Colorado at Boulder, and Nicholas Brummell of the University of California at Santa Cruz.

Flow zone

The sun is a white-hot ball of plasma that's boiling on its surface. This boiling region is called the "convection zone," where layers and plumes of plasma roil and flow. The convection zone comprises the top one-third of the sun's radius and stretches about 200,000 kilometres below the surface.

"One of the basic ideas for how to start a dynamo is that you need a region where there's a lot of plasma moving past other plasma, and that shearing motion converts kinetic energy into magnetic energy," Burns explains. "People had thought that the sun's magnetic field is created by the motions at the very bottom of the convection zone."

To pin down exactly where the sun's magnetic field originates, other scientists have used large three-dimensional simulations to try to solve for the flow of plasma throughout the many layers of the sun's interior. "Those simulations require millions of hours on national supercomputing facilities, but what they produce is still nowhere near as turbulent as the actual sun," Burns says.

Rather than simulating the complex flow of plasma throughout the entire body of the sun, Burns and his colleagues wondered whether studying the stability of plasma flow near the surface might be enough to explain the origins of the dynamo process.

To explore this idea, the team first used data from the field of "helioseismology," where

scientists use observed vibrations on the sun's surface to determine the average structure and flow of plasma beneath the surface.
"If you take a video of a drum and watch how it vibrates in slow motion, you can work out the drumhead's shape and stiffness from the vibrational modes," Burns says. "Similarly, we can use vibrations that we see on the solar surface to infer the average structure on the inside."

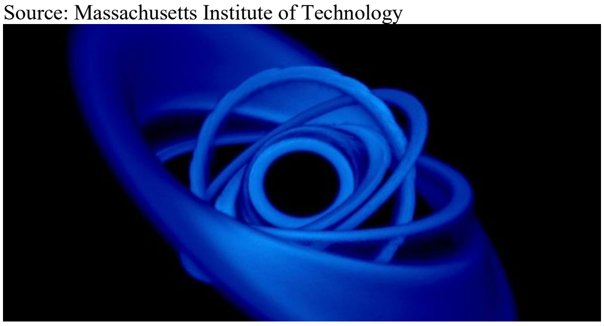
Solar onion

For their new study, the researchers collected models of the sun's structure from helioseismic observations. "These average flows look sort like an onion, with different layers of plasma rotating past each other," Burns explains. "Then we ask: Are there perturbations, or tiny changes in the flow of plasma, that we could superimpose on top of this average structure, that might grow to cause the sun's magnetic field?"
To look for such patterns, the team utilized the Dedalus Project -- a numerical framework that Burns developed that can simulate many types of fluid flows with high precision. The code has been applied to a wide range of problems, from modelling the dynamics inside individual cells, to ocean and atmospheric circulations.
"My collaborators have been thinking about the solar magnetism problem for years, and the capabilities of Dedalus have now reached the point where we could address it," Burns says.
The team developed algorithms that they incorporated into Dedalus to find self-reinforcing changes in the sun's average surface flows. The algorithm discovered new patterns that could grow and result in realistic solar activity. In particular, the team found patterns that match the locations and timescales of sunspots that have been have observed by astronomers since Galileo in 1612.
Sunspots are transient features on the surface of the sun that are thought to be shaped by the sun's magnetic field. These relatively cooler regions appear as dark spots in relation to the rest of the sun's white-hot surface.
Astronomers have long observed that sunspots occur in a cyclical pattern, growing and receding every 11 years, and generally gravitating around the equator, rather than near the poles.
In the team's simulations, they found that certain changes in the flow of plasma, within just the top 5 to 10 percent of the sun's surface layers, were enough to generate magnetic structures in the same regions. In contrast, changes in deeper layers produce less realistic solar fields that are concentrated near the poles, rather than near the equator.
The team was motivated to take a closer look at flow patterns near the surface as conditions there resembled the unstable plasma flows in entirely different systems: the accretion disks around black holes. Accretion disks are massive disks of gas and stellar dust that rotate in towards a black hole, driven by the "magnetorotational instability," which generates turbulence in the flow and causes it to fall inward.
Burns and his colleagues suspected that a similar phenomenon is at play in the sun, and that the magnetorotational instability in the sun's outermost layers could be the first step in generating the sun's magnetic field.
"I think this result may be controversial," he ventures. "Most of the community has been focused on finding dynamo action deep in the sun. Now we're showing there's a different mechanism that seems to be a better match to observations." Burns says that the team is continuing to study if the new surface field patterns can generate individual sunspots and the full 11-year solar cycle.
This research was supported, in part, by NASA.

- Using wobbling stellar material, astronomers measure the spin of a supermassive black hole for the first time

The results offer a new way to probe supermassive black holes and their evolution across the universe

Date: May 22, 2024
Source: Massachusetts Institute of Technology



Astronomers at MIT, NASA, and elsewhere have a new way to measure how fast a black hole spins, by using the wobbly aftermath from its stellar feasting.
The method takes advantage of a black hole tidal disruption event -- a blazingly bright moment when a black hole exerts tides on a

passing star and rips it to shreds. As the star is disrupted by the black hole's immense tidal forces, half of the star is blown away, while the other half is flung around the black hole, generating an intensely hot accretion disk of rotating stellar material.

The MIT-led team has shown that the wobble of the newly created accretion disk is key to working out the central black hole's inherent spin.

In a study appearing in *Nature*, the astronomers report that they have measured the spin of a nearby supermassive black hole by tracking the pattern of X-ray flashes that the black hole produced immediately following a tidal disruption event. The team followed the flashes over several months and determined that they were likely a signal of a bright-hot accretion disk that wobbled back and forth as it was pushed and pulled by the black hole's own spin.

By tracking how the disk's wobble changed over time, the scientists could work out how much the disk was being affected by the black hole's spin, and in turn, how fast the black hole itself was spinning. Their analysis showed that the black hole was spinning at less than 25 percent the speed of light -- relatively slow, as black holes go.

The study's lead author, MIT Research Scientist Dheeraj "DJ" Pasham, says the new method could be used to gauge the spins of hundreds of black holes in the local universe in the coming years. If scientists can survey the spins of many nearby black holes, they can start to understand how the gravitational giants evolved over the history of the universe.

"By studying several systems in the coming years with this method, astronomers can estimate the overall distribution of black hole spins and understand the longstanding question of how they evolve over time," says Pasham, who is a member of MIT's Kavli Institute for Astrophysics and Space Research.

The study's co-authors include collaborators from a number of institutions, including NASA, Masaryk University in the Czech Republic, the University of Leeds, the University of Syracuse, Tel Aviv University, the Polish Academy of Sciences, and elsewhere.

Shredded heat

Every black hole has an inherent spin that has been shaped by its cosmic encounters over time. If, for instance, a black hole has grown mostly through accretion -- brief instances when some material falls onto the disk, this causes the black hole to spin up to quite high speeds. In contrast, if a black hole grows mostly by merging with other black holes, each merger could slow things down as one black hole's spin meets up against the spin of the other.

As a black hole spins, it drags the surrounding space-time around with it. This drag effect is an example of Lense-Thirring precession, a longstanding theory that describes the ways in which extremely strong gravitational fields, such as those generated by a black hole, can pull on the surrounding space and time. Normally, this effect would not be obvious around black holes, as the massive objects emit no light.

But in recent years, physicists have proposed that, in instances such as during a tidal disruption event, or TDE, scientists might have a chance to track the light from stellar debris as it is dragged around. Then, they might hope to measure the black hole's spin.

In particular, during a TDE, scientists predict that a star may fall onto a black hole from any direction, generating a disk of white-hot, shredded material that could be tilted, or misaligned, with respect to the black hole's spin. (Imagine the accretion disk as a tilted donut that is spinning around a donut hole that has its own, separate spin.) As the disk encounters the black hole's spin, it wobbles as the black hole pulls it into alignment. Eventually, the wobbling subsides as the disk settles into the black hole's spin. Scientists predicted that a TDE's wobbling disk should therefore be a measurable signature of the black hole's spin.

"But the key was to have the right observations," Pasham says. "The only way you can do this is, as soon as a tidal disruption event goes off, you need to get a telescope to look at this object continuously, for a very long time, so you can probe all kinds of timescales, from minutes to months."

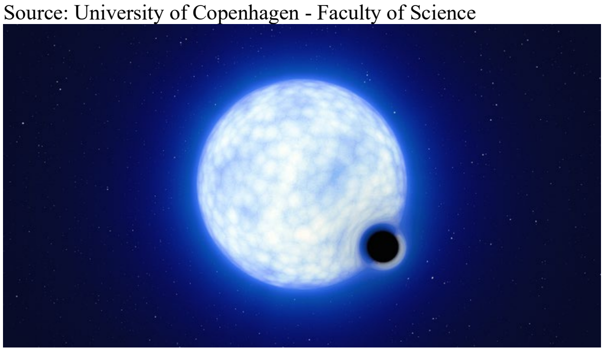
A high-cadence catch

For the past five years, Pasham has looked for tidal disruption events that are bright enough, and near enough, to quickly follow up and track for signs of Lense-Thirring precession. In February of 2020, he and his colleagues got lucky, with the detection of AT2020ocn, a bright flash, emanating from a galaxy about a

billion light years away, that was initially spotted in the optical band by the Zwicky Transient Facility.
From the optical data, the flash appeared to be the first moments following a TDE. Being both bright and relatively close by, Pasham suspected the TDE might be the ideal candidate to look for signs of disk wobbling, and possibly measure the spin of the black hole at the host galaxy's centre. But for that, he would need much more data.
"We needed quick and high-cadence data," Pasham says. "The key was to catch this early on because this precession, or wobble, should only be present early on. Any later, and the disk would not wobble anymore."
The team discovered that NASA's NICER telescope was able to catch the TDE and continuously keep an eye on it over months at a time. NICER -- an abbreviation for Neutron star Interior Composition ExploreR -- is an X-ray telescope on the International Space Station that measures X-ray radiation around black holes and other extreme gravitational objects.
Pasham and his colleagues looked through NICER's observations of AT2020ocn over 200 days following the initial detection of the tidal disruption event. They discovered that the event emitted X-rays that appeared to peak every 15 days, for several cycles, before eventually petering out. They interpreted the peaks as times when the TDE's accretion disk wobbled face-on, emitting X-rays directly toward NICER's telescope, before wobbling away as it continued to emit X-rays (similar to waving a flashlight toward and away from someone every 15 days).
The researchers took this pattern of wobbling and worked it into the original theory for Lense-Thirring precession. Based on estimates of the black hole's mass, and that of the disrupted star, they were able to come up with an estimate for the black hole's spin -- less than 25 percent the speed of light.
Their results mark the first time that scientists have used observations of a wobbling disk following a tidal disruption event to estimate the spin of a black hole. As new telescopes such as the Rubin Observatory come online in the coming years, Pasham foresees more opportunities to pin down black hole spins.
"The spin of a supermassive black hole tells you about the history of that black hole," Pasham says. "Even if a small fraction of those that Rubin captures have this kind of signal, we now have a way to measure the spins of hundreds of TDEs. Then we could make a big statement about how black holes evolve over the age of the universe."
This research was funded, in part, by NASA and the European Space Agency.

- Complete Stellar Collapse: Unusual star system proves that stars can die quietly

Date: May 21, 2024
Source: University of Copenhagen - Faculty of Science



VFTS_243 in the Tarantula_Nebula. L. Calçada/The European Southern Observatory [La Observatorio Europeo Austral] [Observatoire européen austral][Europäische Südsternwarte](EU)(CL)

University of Copenhagen astrophysicists help explain a mysterious phenomenon, whereby stars suddenly vanish from the night sky. Their study of an unusual binary star system has resulted in convincing evidence that massive stars can completely collapse and become black holes without a supernova explosion.

One day, the star at the centre of our own solar system, the Sun, will begin to expand until it engulfs Earth. It will then become increasingly unstable until it eventually contracts into a small and dense object known as a white dwarf.

However, if the Sun were of a weight class roughly eight times greater or more, it would probably go out with a huge bang -- as a supernova. Its collapse would culminate into an explosion, ejecting energy and mass into space with enormous force, prior to leaving behind a neutron star or a black hole in its wake.

While this is basic knowledge about how massive stars die, there remains plenty to understand about the starry skies above and the spectacular death of these stars in particular.

New research by astrophysicists at the University of Copenhagen's Niels Bohr Institute presents the strongest evidence to date that very massive stars can succumb with far more stealth and discretion than as supernovae. Indeed, their investigation suggests that, with enough mass, a star's gravitational pull can be so strong that no explosion takes place upon its death. Instead, the star can go through what is known as a complete collapse.

"We believe that the core of a star can collapse under its own weight, as happens to massive stars in the final phase of their lives. But instead of the contraction culminating into a bright supernova explosion that would outshine its own galaxy, expected for stars more than eight times as massive as the Sun, the collapse continues until the star becomes a black hole," explains first author Alejandro Vigna-Gómez, who was a postdoc at the Niels Bohr Institute when this study set in motion.

This discovery is linked to the phenomenon of disappearing stars, which has interested astronomers in recent years, and it may provide both a clear-cut example as well as a plausible scientific explanation for phenomena of this kind.

"Were one to stand gazing up at a visible star going through a total collapse, it might, just at the right time, be like watching a star suddenly extinguish and disappear from the heavens. The collapse is so complete that no explosion occurs, nothing escapes and one wouldn't see any bright supernova in the night sky. Astronomers have actually observed the sudden disappearance of brightly shining stars in recent times. We cannot be sure of a connection, but the results we have obtained from analysing VFTS 243 has brought us much closer to a credible explanation," says Alejandro Vigna-Gómez.

An unusual star system with no signs of an explosion

This discovery has been prompted by the recent observation of an unusual binary star system at the edge of our galaxy called VFTS 243. Here, a large star and black hole roughly 10 times more massive than our Sun orbit one another.

Scientists have known about the existence of such binary star systems in the Milky Way for decades, where one of the stars has become a black hole. But the recent discovery of VFTS 243, just beyond the Milky Way in the Large Magellanic Cloud, is something truly special.

"Normally, supernova events in star systems can be measured in various ways after they occur. But despite the fact that VFTS 243 contains a star that has collapsed into a black hole, the traces of an explosion are nowhere to be found. VFTS 243 is an extraordinary system. The orbit of the system has barely changed since the collapse of the star into a black hole," says Alejandro Vigna-Gómez.

The researchers have analysed the observational data for a range of signs that would be expected from a star system having undergone a supernova-explosion in the past. Generally, they found evidence of such an event minor and unconvincing.

The system does not show sign of a significant "natal kick," an acceleration of the orbiting objects. It is also very symmetrical, almost perfectly circular in its orbit, and remaining signs from the energy release during the core collapse of the former star points to a type of energy consistent with complete collapse.

"Our analysis unequivocally points to the fact that the black hole in VFTS 243 was most likely formed immediately, with the energy mainly being lost via neutrinos," says Professor Irene Tamborra from the Niels Bohr Institute, who also participated in the study.

A benchmark system for future studies

According to Professor Tamborra, the VFTS 243 system opens the possibility for finally comparing a range of astrophysics theories and model calculations with actual observations. She expects that the star system will be important for studying stellar evolution and collapse.

"Our results highlight VFTS 243 as the best observable case so far for the theory of stellar black holes formed through total collapse, where the supernova explosion fails and which our models have shown to be possible. It is an important reality check for these models. And we certainly expect that the system will serve as a crucial benchmark for future research into stellar evolution and collapse," says the professor.

Background Information

The missing "natal kick" and other (lacking) signs of a supernova

The violent forces of a supernova directly affect the newborn neutron stars or black holes left by it, because of the asymmetric emission of matter during the explosion. This is what the researchers refer to as a "natal kick." This kick causes the compact object to accelerate. A natal kick will normally give neutron stars a measurable speed of 100-1000 km per second. The speed is expected to be less for black holes, but still significant.

Because the black hole in the VFTS 243 system only appears to have been accelerated to roughly 4 km/s, it shows no sign of having received a substantial natal kick, like would be expected had it undergone a supernova.

Similarly, the symmetry of a star system's orbit usually shows signs that it has felt the impact of a violent supernova explosion, because of the ejection of matter that happens. Instead, the researchers found symmetry.

"The orbit of VFTS is almost circular and our analysis indicates there are no signs of large asymmetries during collapse. This again indicates the absence of an explosion," says Alejandro Vigna Gomez.

A burst of energy

Analysing the orbit of the binary star system, the team has also been able to calculate the amount of mass and energy released during the formation of the black hole.

Their estimations are consistent with a scenario in which the smaller kick imparted during the stellar collapse was not due to baryonic matter, which includes neutrons and protons, rather to so-called neutrinos. Neutrinos have very little mass and interact very weakly. This is another indication that the system did not experience an explosion.

Black holes

Not even light can escape from black holes. As such, they cannot be observed directly. However, some black holes can be identified due to the large amounts of energy being emitted from the gases rotating around them. Others, as in the case of VFTS 243, can be observed by the influence they have on stars with which they orbit.

In general, astronomers believe there to be three types of black holes:

Stellar black holes -- such as those of the VFTS 243 system -- form when stars with more than eight times the mass of the Sun collapse. Scientists believe there may be as many as 100 million of these in our galaxy alone.

Supermassive black holes -- 100,000 -- 10 billion times the mass of the Sun -- are thought to be at the centre of nearly all galaxies. Sagittarius A* is the supermassive black hole at centre of our galaxy, the Milky Way.

Intermediate-mass black holes (IMBH) -- 100-100,000 times the mass of our Sun -- were long a missing link. In recent years, a number of credible candidates have emerged.

There are also theories that describe other types of black holes, which have yet to be discovered. One of these, so-called Primordial black holes, are supposed to have formed in the early universe and could theoretically be microscopic.

Disappearing stars

In modern times, there have been many observations of stars that inexplicably disappear.

"A Survey about Nothing" led by astrophysicist Chris Kochanek is an example of the research efforts actively looking for disappearing stars and explanations for their disappearance.

The curious reader can also delve into historical descriptions. These often have to do with suddenly luminous stars that disappear consistent with supernova scenarios. But there are other stories about suddenly disappearing stars, such as the Greek myth associated with the Pleiades star cluster, commonly known as the Seven Sisters. The Pleiades myth describes the seven daughters of the titan Atlas and nymph Pleione. According to the myth, one of their daughters married a human and went into hiding, which provides a very unscientific, but beautiful explanation for why we only see six stars in the Pleiades.

- Webb Telescope offers first glimpse of an exoplanet's interior

Methane found in WASP-107 b reveals core mass, turbulent skies

Date: May 20, 2024
Source: Johns Hopkins University

Artist's concept of WASP-107 b, a warm Neptune exoplanet about 200 light-years away. Image: ROBERTO MOLAR CANDANOSA/JOHNS HOPKINS UNIVERSITY

A surprisingly low amount of methane and a super-sized core hide within the cotton candy-like planet WASP-107 b.

The revelations, based on data obtained by the James Webb Space Telescope, mark the first measurements of an exoplanet's core mass and will likely underpin future studies of planetary atmospheres and interiors, a key aspect in the search for habitable worlds beyond our solar system.

"Looking into the interior of a planet hundreds of light-years away sounds almost impossible, but when you know the mass, radius, atmospheric composition, and hotness of its interior, you've got all the pieces you need to get an idea of what's inside and how heavy that core is," said lead author David Sing, a Bloomberg Distinguished Professor of Earth and Planetary Sciences at Johns Hopkins University. "This is now something we can do for lots of different gas planets in various systems."

Published today in *Nature*, the research shows the planet has a thousand times less methane than expected and a core 12 times more massive than Earth's.

A giant planet wrapped by a scorching atmosphere as fluffy as cotton, WASP-107 b orbits a star about 200 light-years away. It is puffy because of its build: a Jupiter-sized world with only a tenth of that planet's mass. Even though it has methane -- a building block of life on Earth -- the planet is not considered habitable because of its proximity to its parent star and lack of a solid surface. But it could hold important clues about late-stage planetary evolution.

In a separate study published today in *Nature*, other scientists also spotted methane with the Webb telescope and provided similar insights about the planet's size and density.

"We want to look at planets more similar to the gas giants in our own solar system, which have a lot of methane in their atmospheres," Sing said. "This is where the story of WASP-107 b got really interesting, because we didn't know why the methane levels were so low."

The new methane measurements suggest the molecule transforms into other compounds as it flows upward from the planet's interior, interacting with a concoction of other chemicals and starlight in the upper atmosphere. The team also measured sulphur dioxide, water vapor, carbon dioxide, and carbon monoxide -- and found WASP-107 b has more heavy elements than Uranus and Neptune.

The profile of the planet's chemistry is starting to reveal key pieces in the puzzle of how planetary atmospheres behave in extreme conditions, Sing said. His team will conduct similar observations over the next year on an additional 25 planets with the Webb telescope.

"We had never been able to study this mixing process in an exoplanet atmosphere in detail, so this will go a long way in understanding how these dynamic chemical reactions operate," Sing said. "It's something we definitely need as we start looking at rocky planets and biomarker signatures."

Scientists had speculated that the planet's overinflated radius resulted from a source of heat inside, said Zafar Rustamkulov, a Johns Hopkins doctoral student in planetary science who co-led the research. By combining atmospheric and interior physics models with Webb's data of WASP-107 b, the team accounted for how the planet's thermodynamics influences its observable atmosphere.

"The planet has a hot core, and that heat source is changing the chemistry of the gases deeper down, but it's also driving this strong, convective mixing bubbling up from the interior," Rustamkulov said. "We think this heat is causing the chemistry of the gases to change, specifically destroying methane and making elevated amounts of carbon dioxide and carbon monoxide."

The new findings also represent the clearest connection scientists have been able to make about the interior of an exoplanet and the top of its atmosphere, Rustamkulov said. Last year the Webb telescope spotted sulphur dioxide about 700 light-years away in a different exoplanet called WASP-39, providing the first evidence of an atmospheric compound created by starlight-driven reactions.

The Johns Hopkins team is now focusing on what might be keeping the core hot, and expects forces might be in play similar to those causing high and low tides in Earth's oceans. They plan to test whether the planet is being stretched and pulled by its star and how that might account for the core's high heat.

Other study authors are Daniel P. Thorngren and Elena Manjavacas of Johns Hopkins University; Joanna K. Barstow of the Open University; Pascal Tremblin of Université Paris-Saclay; Catarina Alves de Oliveira, Stephan M. Birkmann, and Pierre Ferruit of the European Space Agency; Tracy L. Beck, Néstor Espinoza, Amélie Gressier, Marco Sirianni, and Jeff A. Valenti of the Space Telescope Science Institute; Ryan C. Challener of Cornell University; Nicolas Crouzet, Giovanna Giardino, and Nikole K. Lewis of Leiden University; Elspeth K. H. Lee; Roberto Maiolino of University of Cambridge; and Bernard J. Rauscher of NASA Goddard Space Flight Centre.

This research is based on data obtained from the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy Inc., under NASA contract NAS 5-03127.

- ❖ Hubble views the dawn of a sun-like star

Date: May 15, 2024
Source: NASA/Goddard Space Flight Centre

This NASA Hubble Space Telescope image captures a triple-star star system.
NASA, ESA, G. Duchene (Universite de Grenoble I); Image Processing: Gladys Kober (NASA/Catholic University of America)

Looking like a glittering cosmic geode, a trio of dazzling stars blaze from the hollowed-out cavity of a reflection nebula in this new image from NASA's Hubble Space Telescope. The triple-star system is made up of the variable star HP Tau, HP Tau G2, and HP Tau G3. HP Tau is known as a T Tauri star, a type of young variable star that hasn't begun nuclear fusion yet but is beginning to evolve into a hydrogen-fuelled star similar to our Sun. T Tauri stars tend to be younger than 10 million years old — in comparison, our Sun is around 4.6 billion years old — and are often found still swaddled in the clouds of dust and gas from which they formed.

As with all variable stars, HP Tau's brightness changes over time. T Tauri stars are known to have both periodic and random fluctuations in brightness. The random variations may be due to the chaotic nature of a developing young star, such as instabilities in the accretion disk of dust and gas around the star, material from that disk falling onto the star and being consumed, and flares on the star's surface. The periodic changes may be due to giant sunspots rotating in and out of view.

Curving around the stars, a cloud of gas and dust shines with their reflected light.

Reflection nebulae do not emit visible light of their own, but shine as the light from nearby stars bounces off the gas and dust, like fog illuminated by the glow of a car's headlights.

HP Tau is located approximately 550 light-years away in the constellation Taurus.

Hubble studied HP Tau as part of an investigation into protoplanetary disks, the disks of material around stars that coalesce into planets over millions of years.

- Detection of an Earth-sized exoplanet orbiting the ultracool dwarf star SPECULOOS-3

Date: May 15, 2024
Source: University of Liège

Artist's concept of Earth-sized exoplanet SPECULOOS-3 b. The SPECULOOS project in Belgium helped an international team of astronomers discover the planet, 55 light-years from Earth. SPECULOOS-3 is only the 2nd planetary system found so far around an ultracool dwarf star. The other is the famous TRAPPIST-1 system. Image via NASA/ JPL-Caltech.

The SPECULOOS project, led by the astronomer Michaël Gillon from the University of Liège, has just discovered a new Earth-sized exoplanet around SPECULOOS-3, an "ultracool dwarf" star as small as Jupiter, twice as cold as our Sun, and located 55 light-years from Earth. After the famous TRAPPIST-1, SPECULOOS 3 is the second planetary system discovered around this type of star.

Ultra-cool dwarf stars are the least massive stars in our Universe, similar in size to Jupiter, more than twice as cold, ten times less massive and a hundred times less luminous than our Sun. Their lifespan is over a hundred times longer than that of our star, and they will be the last stars to shine when the Universe becomes cold and dark. Although they are far more common in the Cosmos than Sun-like stars, ultra-cool dwarf stars are still poorly understood due to their low luminosity. In particular, very little is known about their planets, even though they represent a significant fraction of the planetary population of our Milky Way.

It's against this backdrop that the SPECULOOSconsortium, led by the University of Liège, has just announced the discovery of a new Earth-sized planet orbiting a nearby ultra-cool dwarf star. The SPECULOOS-3 b exoplanet lies around 55 light-years from Earth (which is very close on a cosmic scale! Our galaxy, the Milky Way, stretches over 100,000 light-years).

SPECULOOS 3 is only the second planetary system to be discovered around this type of star: "SPECULOOS-3 b is practically the same size as our planet," explains the astronomer Michaël Gillon, first author of the article published in Nature Astronomy. A year, i.e. an orbit around the star, lasts around 17 hours. Days and nights, on the other hand, should never end. We believe that the planet rotates synchronously, so that the same side, called the day side, always faces the star, just like the Moon does for the Earth. On the other hand, the night side hand, would be locked in endless darkness."

The SPECULOOS (Search for Planets EClipsing ULtra-cOOl Stars) project, initiated and led by astronomer Michaël Gillon, has been specially designed to search for exoplanets around the nearest ultra-cold dwarf stars. These stars are scattered across the sky, so you must observe them one by one, over a period of weeks, to have a good chance of detecting transiting planets," continues the researcher. This requires a dedicated network of professional robotic telescopes." This is the concept behind SPECULOOS, jointly run by the Universities of Liège, Cambridge, Birmingham, Berne, MIT and ETH Zürich. "We designed SPECULOOS specifically to observe nearby ultra-cool dwarf stars in search of rocky planets that lend themselves well to detailed studies," comments Laetitia Delrez, astronomer at the University of Liège. In 2017, our SPECULOOS prototype using the TRAPPIST telescope discovered the famous TRAPPIST-1 system made up of seven Earth-sized planets, including several potentially habitable ones. This was an excellent start!"

The SPECULOOS-3 star is more than twice as cold as our sun, with an average temperature of around 2,600°C. Due to its hyper-short orbit, the planet receives almost sixteen times more energy per second than the Earth does from the Sun and is therefore literally bombarded with high-energy radiation. "In such an environment, the presence of an atmosphere around the planet is highly unlikely," says Julien de Wit, MIT professor and co-director of the SPECULOOS Northern Observatory and its Artemis telescope, co-developed by the University of Liège and MIT, and the mainstay of this discovery. The fact that this planet has no atmosphere could be a plus in several respects. For example, it could enable us to learn a great deal about ultra-cool dwarf stars, which in turn will make possible more indepth studies of their potentially habitable planets."

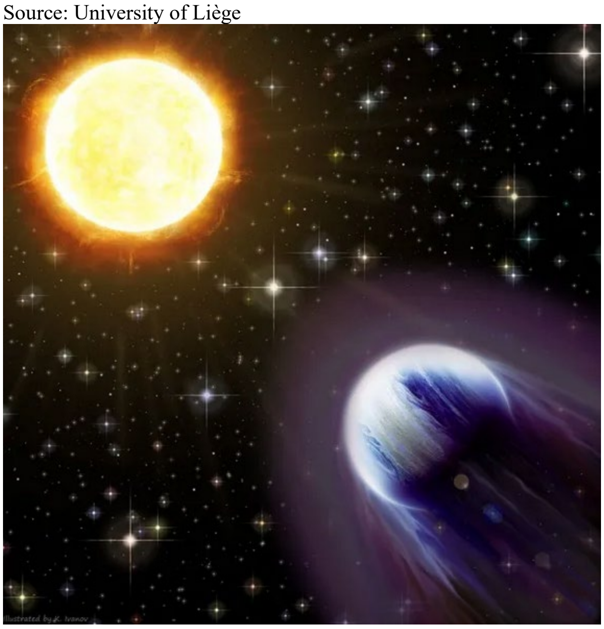
SPECULOOS-3 b is proving to be an excellent target for the JWST space telescope, to be launched in 2021, whose data will revolutionize our vision of the Universe. "With the JWST, we could even study the mineralogy of the planet's surface!" enthuses Elsa Ducrot**, a** former researcher at the University of Liège now based at Paris Observatory**.**

"This discovery demonstrates the ability of our SPECULOOS-North observatory to detect Earth-sized exoplanets suitable for detailed study. And this is just the beginning! Thanks to the financial support of the Walloon Region and the University of Liège, two new telescopes, Orion and Apollo, will soon join Artemis on the plateau of the Teide volcano in Tenerife, to speed up the hunt for these fascinating planets" concludes Michaël Gillon.

- ❖ WASP-193b, a giant planet with a density similar to that of cotton candy

This exoplanet is larger but seven times less massive than Jupiter and is the second least dense planet discovered to date

Date: May 14, 2024
Source: University of Liège



Around a star in our Milky Way galaxy, astronomers have discovered an extremely low-density planet that is as light as cotton candy. The new planet, named WASP-193b, appears to dwarf Jupiter in size, yet it is a fraction of its density. Credit: K. Ivanov/MIT.

An international team led by researchers from the EXOTIC Laboratory of the University of Liège, in collaboration with MIT and the Astrophysics Institute in Andalusia, has just discovered WASP-193b, an extraordinarily low-density giant planet orbiting a distant Sun-like star.

This new planet, located 1,200 light-years from Earth, is 50% larger than Jupiter but seven times less massive, giving it an extremely low density comparable to that of cotton candy. "WASP-193b is the second least dense planet discovered to date, after Kepler-51d, which is much smaller," explains Khalid Barkaoui, a Postdcotral Researcher at ULiège's EXOTIC Laboratory and first author of the article published in Nature Astronomy. Its extremely low density makes it a real anomaly among the more than five thousand exoplanets discovered to date. This extremely-low-density cannot be reproduced by standard models of irradiated gas giants, even under the unrealistic assumption of a coreless structure."

The new planet was initially spotted by the Wide-Angle Search for Planets (WASP), an international collaboration of academic institutions that together operated two robotic observatories, one in the northern hemisphere and the other in the south. Each observatory used an array of wide-angle cameras to measure the brightness of thousands of individual stars across the entire sky. In data taken between 2006 and 2008, and again from 2011 to 2012, the WASP-South observatory detected periodic transits, or dips in light, from the star WASP-193. Astronomers determined that the star's periodic dips in brightness were consistent with a planet passing in front of the star every 6.25 days. The scientists measured the amount of light the planet blocked with each transit, which gave them an estimate of the planet's size.

The team used then the TRAPPIST-South and SPECULOOS-South observatories -- directed by Michaël Gillon, FNRS Research Director and astrophysicist at ULiège -- located in the Atacama Desert in Chile to measure the planetary signal in different wavelengths and to validate the planetary nature of the eclipsing object. Finally, they also used spectroscopic observations collected by the HARPS and CORALIE spectrographs -- also located in Chile (ESO)- to measure the mass of the planet. To their great surprise, the accumulated measurements revealed an extremely low density for the planet. Its mass and its size, they calculated, were about 0.14 and 1.5 that of Jupiter, respectively. The resulting density came out to about 0.059 grams per cubic centimetre. Jupiter's density, in contrast, is about 1.33 grams per cubic centimetre; and Earth is a more substantial 5.51 grams per cubic centimetre. One of the materials closest in density to the new, puffy

planet, is cotton candy, which has a density of about 0.05 grams per cubic centimetre.
"The planet is so light that it's difficult to think of an analogous, solid-state material," says Julien de Wit, professor at Massachusetts Institute of Technology (MIT) and co-author. "The reason why it's close to cotton candy is because both are pretty much air. The planet is basically super fluffy."
The researchers suspect that the new planet is made mostly from hydrogen and helium, like most other gas giants in the galaxy. For WASP-193b, these gases likely form a hugely inflated atmosphere that extends tens of thousands of kilometres farther than Jupiter's own atmosphere. Exactly how a planet can inflate so much is a question that no existing theory of planetary formation can yet answer. It certainly requires a significant deposit of energy deep into the planet's interior, but the details of the mechanism are not yet understood. "We don't know where to put this planet in all the formation theories we have right now, because it's an outlier of all of them. We cannot explain how this planet was formed. Looking more closely at its atmosphere will allow us to constrain an evolutionary path of this planet, adds Francisco Pozuelos, astronomer at the Instituto de Astrofisica de Andalucia (IAA-CSIC, Granada, Spain)."
"WASP-193b is a cosmic mystery. Solving it will require some more observational and theoretical work, notably to measure its atmospheric properties with the JWST space telescope and to confront them to different theoretical mechanisms that possibly result in such an extreme inflation", concludes Khalid Barkaoui.