South Downs Mercury

The monthly circular of South Downs Astronomical Society
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THE FEBRUARY MEETING IS CANCELLED DUE TO COVID-19

We have a virtual meeting Friday 5th March Zoom Meeting 19:30 Dr Steve Barrett Department of Physics University of Liverpool The Beginning of Everything. Email me for joining instructions if you have not already received them

- The cataclysm that killed the dinosaurs

New theory explains possible origin of plummeting Chicxulub impactor that struck off Mexico

Date: February 15, 2021
Source: Harvard University

Illustration of asteroid heading toward Earth (stock image).
Credit: © Marcos Silva / stock.adobe.com

It was tens of miles wide and forever changed history when it crashed into Earth about 66 million years ago.

The Chicxulub impactor, as it's known, left behind a crater off the coast of Mexico that spans 93 miles and goes 12 miles deep. Its devastating impact brought the reign of the dinosaurs to an abrupt and calamitous end by triggering their sudden mass extinction, along with the end of almost three-quarters of the plant and animal species then living on Earth.

The enduring puzzle has always been where the asteroid or comet that set off the destruction originated, and how it came to strike the Earth. And now a pair of Harvard researchers believe they have the answer.

In a study published in *Scientific Reports*, Avi Loeb, Frank B. Baird Jr. Professor of Science at Harvard, and Amir Siraj '21, an astrophysics concentrator, put forth a new theory that could explain the origin and journey of this catastrophic object and others like it.

Using statistical analysis and gravitational simulations, Loeb and Siraj show that a significant fraction of a type of comet originating from the Oort cloud, a sphere of debris at the edge of the solar system, was bumped off-course by Jupiter's gravitational field during its orbit and sent close to the sun, whose tidal force broke apart pieces of the rock. That increases the rate of comets like Chicxulub (pronounced Chicks-uh-lub) because these fragments cross the Earth's orbit and hit the planet once every 250 to 730 million years or so.

"Basically, Jupiter acts as a kind of pinball machine," said Siraj, who is also co-president of Harvard Students for the Exploration and Development of Space and is pursuing a master's degree at the New England Conservatory of Music. "Jupiter kicks these incoming long-period comets into orbits that bring them very close to the sun."

It's because of this that long-period comets, which take more than 200 years to orbit the sun, are called sun grazers, he said.

"When you have these sun grazers, it's not so much the melting that goes on, which is a pretty small fraction relative to the total mass, but the comet is so close to the sun that the part that's closer to the sun feels a stronger gravitational pull than the part that is farther from the sun, causing a tidal force" he said. "You get what's called a tidal disruption event and so these large comets that come really close to the sun break up into smaller comets. And basically, on their way out, there's a statistical chance that these smaller comets hit the Earth."

The calculations from Loeb and Siraj's theory increase the chances of long-period comets impacting Earth by a factor of about 10, and

show that about 20 percent of long-period comets become sun grazers. That finding falls in line with research from other astronomers. The pair claim that their new rate of impact is consistent with the age of Chicxulub, providing a satisfactory explanation for its origin and other impactors like it.

"Our paper provides a basis for explaining the occurrence of this event," Loeb said. "We are suggesting that, in fact, if you break up an object as it comes close to the sun, it could give rise to the appropriate event rate and also the kind of impact that killed the dinosaurs."

Loeb and Siraj's hypothesis might also explain the makeup of many of these impactors.

"Our hypothesis predicts that other Chicxulub-size craters on Earth are more likely to correspond to an impactor with a primitive (carbonaceous chondrite) composition than expected from the conventional main-belt asteroids," the researchers wrote in the paper.

This is important because a popular theory on the origin of Chicxulub claims the impactor is a fragment of a much larger asteroid that came from the main belt, which is an asteroid population between the orbit of Jupiter and Mars. Only about a tenth of all main-belt asteroids have a composition of carbonaceous chondrite, while it's assumed most long-period comets have it. Evidence found at the Chicxulub crater and other similar craters that suggests they had carbonaceous chondrite. This includes an object that hit about 2 billion years ago and left the Vredefort crater in South Africa, which is the largest confirmed crater in Earth's history, and the impactor that left the Zhamanshin crater in Kazakhstan, which is the largest confirmed crater within the last million years.

The researchers say that composition evidence supports their model and that the years the objects hit support both their calculations on impact rates of Chicxulub-sized tidally disrupted comets and for smaller ones like the impactor that made the Zhamanshin crater. If produced the same way, they say those would strike Earth once every 250,000 to 730,000 years.

Loeb and Siraj say their hypothesis can be tested by further studying these craters, others like them, and even ones on the surface of the moon to determine the composition of the impactors. Space missions sampling comets can also help.

Aside from composition of comets, the new Vera Rubin Observatory in Chile may be able to see the tidal disruption of long-period comets after it becomes operational next year.

"We should see smaller fragments coming to Earth more frequently from the Oort cloud," Loeb said. "I hope that we can test the theory by having more data on long-period comets, get better statistics, and perhaps see evidence for some fragments."

Loeb said understanding this is not just crucial to solving a mystery of Earth's history but could prove pivotal if such an event were to threaten the planet again.

"It must have been an amazing sight, but we don't want to see that side," he said.

- ❖ Hubble uncovers concentration of small black holes

Date: February 11, 2021
Source: ESA/Hubble Information Centre

Hubble Space Telescope (stock image).
Credit: © marcel / stock.adobe.com

Globular clusters are extremely dense stellar systems, in which stars are packed closely together. They are also typically very old -- the globular cluster that is the focus of this study, NGC 6397, is almost as old as the Universe itself. It resides 7800 light-years away, making it one of the closest globular clusters to Earth. Because of its very dense nucleus, it is known as a core-collapsed cluster.

When Eduardo Vitral and Gary A. Mamon of the Institut d'Astrophysique de Paris set out to study the core of NGC 6397, they expected to find evidence for an "intermediate-mass" black hole (IMBH). These are smaller than the supermassive black holes that lie at the cores of large galaxies, but larger than stellar-mass black holes formed by the collapse of massive stars. IMBH are the long-sought "missing link" in black hole evolution and their mere existence is hotly debated, although

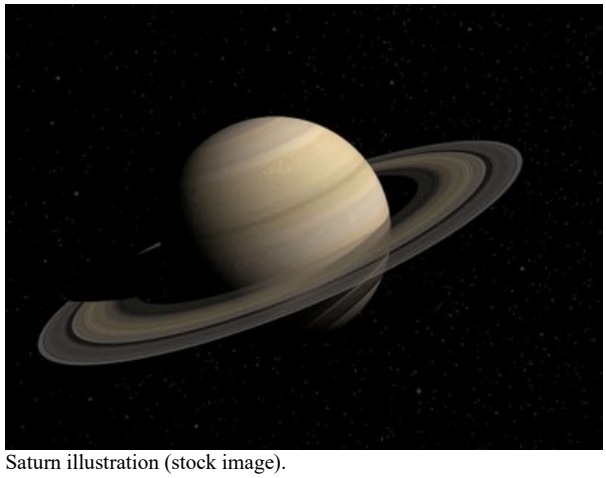
a few candidates have been found ([1], for example).
To look for the IMBH, Vitral and Mamon analysed the positions and velocities of the cluster's stars. They did this using previous estimates of the stars' proper motions [2] from Hubble images of the cluster spanning several years [3], in addition to proper motions provided by ESA's Gaia space observatory, which precisely measures the positions, distances and motions of stars. Knowing the distance to the cluster allowed the astronomers to translate the proper motions of these stars into velocities.
"Our analysis indicated that the orbits of the stars are close to random throughout the globular cluster, rather than systematically circular or very elongated," explained Mamon.
"We found very strong evidence for invisible mass in the dense central regions of the cluster, but we were surprised to find that this extra mass is not point-like but extended to a few percent of the size of the cluster," added Vitral.
This invisible component could only be made up of the remnants (white dwarfs, neutron stars, and black holes) of massive stars whose inner regions collapsed under their own gravity once their nuclear fuel was exhausted. The stars progressively sank to the cluster's centre after gravitational interactions with nearby less massive stars, leading to the small extent of the invisible mass concentration. Using the theory of stellar evolution, the scientists concluded that the bulk of the unseen concentration is made of stellar-mass black holes, rather than white dwarfs or neutron stars that are too faint to observe.
Two recent studies had also proposed that stellar remnants and in particular, stellar-mass black holes, could populate the inner regions of globular clusters.
"Our study is the first finding to provide both the mass and the extent of what appears to be a collection of mostly black holes in a core-collapsed globular cluster," said Vitral.
"Our analysis would not have been possible without having both the Hubble data to constrain the inner regions of the cluster and the Gaia data to constrain the orbital shapes of the outer stars, which in turn indirectly constrain the velocities of foreground and background stars in the inner regions," added Mamon, attesting to an exemplary international collaboration.
The astronomers also note that this discovery raises the question of whether mergers of these tightly packed black holes in core-collapsed globular clusters may be an important source of gravitational waves recently detected by the Laser Interferometer Gravitational-Wave Observatory (LIGO) experiment.

Notes

[1] In 2020, new data from the NASA/ESA Hubble Space Telescope provided the strongest evidence to date for a mid-sized black hole.
[2] Proper motion describes how fast objects move in the sky.
[3] The Hubble data for this study were provided by A. Bellini, who measured the proper motions for over 1.3 million stars in 22 globular clusters, including NGC 6397.
The Hubble Space Telescope is a project of international cooperation between ESA and NASA.

- Saturn's tilt caused by its moons, researchers say

Date: January 21, 2021
Source: CNRS



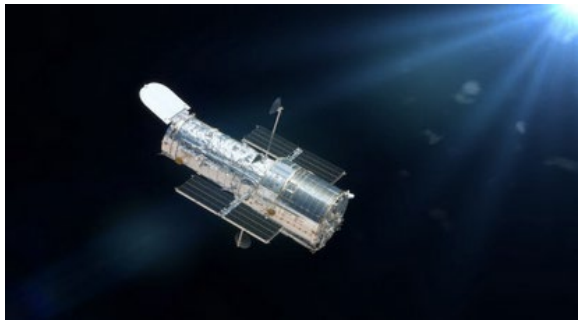
Saturn illustration (stock image).
Credit: © Dimitar Marinov / stock.adobe.com

Two scientists from CNRS and Sorbonne University working at the Institute of Celestial Mechanics and Ephemeris Calculation (Paris Observatory -- PSL/CNRS) have just shown that the influence of Saturn's satellites can explain the tilt of the rotation axis of the gas giant. Their work, published on 18 January 2021 in the journal *Nature Astronomy*, also predicts that the tilt will increase even further over the next few billion years.
Rather like David versus Goliath, it appears that Saturn's tilt may in fact be caused by its moons. This is the conclusion of recent work carried out by scientists from the CNRS, Sorbonne University and the University of Pisa, which shows that the current tilt of

Saturn's rotation axis is caused by the migration of its satellites, and especially by that of its largest moon, Titan.
Recent observations have shown that Titan and the other moons are gradually moving away from Saturn much faster than astronomers had previously estimated. By incorporating this increased migration rate into their calculations, the researchers concluded that this process affects the inclination of Saturn's rotation axis: as its satellites move further away, the planet tilts more and more.
The decisive event that tilted Saturn is thought to have occurred relatively recently. For over three billion years after its formation, Saturn's rotation axis remained only slightly tilted. It was only roughly a billion years ago that the gradual motion of its satellites triggered a resonance phenomenon that continues today: Saturn's axis interacted with the path of the planet Neptune and gradually tilted until it reached the inclination of 27° observed today.
These findings call into question previous scenarios. Astronomers were already in agreement about the existence of this resonance. However, they believed that it had occurred very early on, over four billion years ago, due to a change in Neptune's orbit. Since that time, Saturn's axis was thought to have been stable. In fact, Saturn's axis is still tilting, and what we see today is merely a transitional stage in this shift. Over the next few billion years, the inclination of Saturn's axis could more than double.
The research team had already reached similar conclusions about the planet Jupiter, which is expected to undergo comparable tilting due to the migration of its four main moons and to resonance with the orbit of Uranus: over the next five billion years, the inclination of Jupiter's axis could increase from 3° to more than 30°.

- Astronomers discover first cloudless, Jupiter-like planet

This marks the second time astronomers have ever observed a cloud-free exoplanet
Date: January 22, 2021
Source: Harvard-Smithsonian Centre for Astrophysics

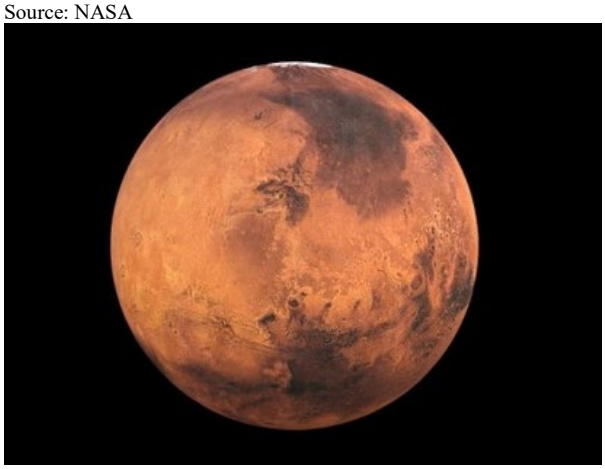

Hubble Space Telescope illustration (stock image).
Credit: © dottedyeti / stock.adobe.com

Astronomers at the Centre for Astrophysics | Harvard & Smithsonian have detected the first Jupiter-like planet without clouds or haze in its observable atmosphere. The findings were published this month in the *Astrophysical Journal Letters*.
Named WASP-62b, the gas giant was first detected in 2012 through the Wide-Angle Search for Planets (WASP) South survey. Its atmosphere, however, had never been closely studied until now.
"For my thesis, I have been working on exoplanet characterization," says Munazza Alam, a graduate student at the Centre for Astrophysics who led the study. "I take discovered planets and I follow up on them to characterize their atmospheres."
Known as a "hot Jupiter," WASP-62b is 575 light years away and about half the mass of our solar system's Jupiter. However, unlike our Jupiter, which takes nearly 12 years to orbit the sun, WASP-62b completes a rotation around its star in just four-and-a-half days. This proximity to the star makes it extremely hot, hence the name "hot Jupiter."
Using the Hubble Space Telescope, Alam recorded data and observations of the planet using spectroscopy, the study of electromagnetic radiation to help detect chemical elements. Alam specifically monitored WASP-62b as it swept in front of its host star three times, making visible light observations, which can detect the presence of sodium and potassium in a planet's atmosphere.
"I'll admit that at first I wasn't too excited about this planet," Alam says. "But once I started to take a look at the data, I got excited."
While there was no evidence of potassium, sodium's presence was strikingly clear. The team was able to view the full sodium absorption lines in their data, or its complete fingerprint. Clouds or haze in the atmosphere would obscure the complete signature of sodium, Alam explains, and astronomers

usually can only make out small hints of its presence.
"This is smoking gun evidence that we are seeing a clear atmosphere," she says.
Cloud-free planets are exceedingly rare; astronomers estimate that less than 7 percent of exoplanets have clear atmospheres, according to recent research. For example, the first and only other known exoplanet with a clear atmosphere was discovered in 2018. Named WASP-96b, it is classified as a hot Saturn.
Astronomers believe studying exoplanets with cloudless atmospheres can lead to a better understanding of how they were formed. Their rarity "suggests something else is going on or they formed in a different way than most planets," Alam says. Clear atmospheres also make it easier to study the chemical composition of planets, which can help identify what a planet is made of.
With the launch of the James Webb Space Telescope later this year, the team hopes to have new opportunities to study and better understand WASP-62b. The telescope's improved technologies, like higher resolution and better precision, should help them probe the atmosphere even closer to search for the presence of more elements, such as silicon.

- ❖ Touchdown! NASA's Mars Perseverance rover safely lands on Red Planet

Date: February 18, 2021
Source: NASA



Mars (stock image).
Credit: © tsuneomp / stock.adobe.com

The largest, most advanced rover NASA has sent to another world touched down on Mars Thursday, after a 203-day journey traversing 293 million miles (472 million kilometres). Confirmation of the successful touchdown was announced in mission control at NASA's Jet Propulsion Laboratory in Southern California at 3:55 p.m. EST (12:55 p.m. PST). Packed with ground-breaking technology, the Mars 2020 mission launched July 30, 2020, from Cape Canaveral Space Force Station in Florida. The Perseverance rover mission marks an ambitious first step in the effort to collect Mars samples and return them to Earth.
"This landing is one of those pivotal moments for NASA, the United States, and space exploration globally -- when we know we are on the cusp of discovery and sharpening our pencils, so to speak, to rewrite the textbooks," said acting NASA Administrator Steve Jurczyk. "The Mars 2020 Perseverance mission embodies our nation's spirit of persevering even in the most challenging of situations, inspiring, and advancing science and exploration. The mission itself personifies the human ideal of persevering toward the future and will help us prepare for human exploration of the Red Planet."
About the size of a car, the 2,263-pound (1,026-kilogram) robotic geologist and astrobiologist will undergo several weeks of testing before it begins its two-year science investigation of Mars' Jezero Crater. While the rover will investigate the rock and sediment of Jezero's ancient lakebed and river delta to characterize the region's geology and past climate, a fundamental part of its mission is astrobiology, including the search for signs of ancient microbial life. To that end, the Mars Sample Return campaign, being planned by NASA and ESA (European Space Agency), will allow scientists on Earth to study samples collected by Perseverance to search for definitive signs of past life using instruments too large and complex to send to the Red Planet.
"Because of today's exciting events, the first pristine samples from carefully documented locations on another planet are another step closer to being returned to Earth," said Thomas Zurbuchen, associate administrator for science at NASA. "Perseverance is the first step in bringing back rock and regolith from Mars. We don't know what these pristine samples from Mars will tell us. But what they could tell us is monumental -- including that life might have once existed beyond Earth."
Some 28 miles (45 kilometres) wide, Jezero Crater sits on the western edge of Isidis Planitia, a giant impact basin just north of the Martian equator. Scientists have determined that 3.5 billion years ago the crater had its own river delta and was filled with water.
The power system that provides electricity and heat for Perseverance through its

exploration of Jezero Crater is a Multi-Mission Radioisotope Thermoelectric Generator, or MMRTG. The U.S. Department of Energy (DOE) provided it to NASA through an ongoing partnership to develop power systems for civil space applications.
Equipped with seven primary science instruments, the most cameras ever sent to Mars, and its exquisitely complex sample caching system -- the first of its kind sent into space -- Perseverance will scour the Jezero region for fossilized remains of ancient microscopic Martian life, taking samples along the way.
"Perseverance is the most sophisticated robotic geologist ever made, but verifying that microscopic life once existed carries an enormous burden of proof," said Lori Glaze, director of NASA's Planetary Science Division. "While we'll learn a lot with the great instruments we have aboard the rover, it may very well require the far more capable laboratories and instruments back here on Earth to tell us whether our samples carry evidence that Mars once harboured life."

Paving the Way for Human Missions

"Landing on Mars is always an incredibly difficult task and we are proud to continue building on our past success," said JPL Director Michael Watkins. "But, while Perseverance advances that success, this rover is also blazing its own path and daring new challenges in the surface mission. We built the rover not just to land but to find and collect the best scientific samples for return to Earth, and it’s incredibly complex sampling system and autonomy not only enable that mission, they set the stage for future robotic and crewed missions."
The Mars Entry, Descent, and Landing Instrumentation 2 (MEDLI2) sensor suite collected data about Mars' atmosphere during entry, and the Terrain-Relative Navigation system autonomously guided the spacecraft during final descent. The data from both are expected to help future human missions land on other worlds more safely and with larger payloads.
On the surface of Mars, Perseverance's science instruments will have an opportunity to scientifically shine. Mastcam-Z is a pair of zoomable science cameras on Perseverance's remote sensing mast, or head, that creates high-resolution, colour 3D panoramas of the Martian landscape. Also located on the mast, the SuperCam uses a pulsed laser to study the chemistry of rocks and sediment and has its own microphone to help scientists better understand the property of the rocks, including their hardness.
Located on a turret at the end of the rover's robotic arm, the Planetary Instrument for X-ray Lithochemistry (PIXL) and the Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals (SHERLOC) instruments will work together to collect data on Mars' geology close-up. PIXL will use an X-ray beam and suite of sensors to delve into a rock's elemental chemistry. SHERLOC's ultraviolet laser and spectrometer, along with its Wide-Angle Topographic Sensor for Operations and eNgineering (WATSON) imager, will study rock surfaces, mapping out the presence of certain minerals and organic molecules, which are the carbon-based building blocks of life on Earth.
The rover chassis is home to three science instruments, as well. The Radar Imager for Mars' Subsurface Experiment (RIMFAX) is the first ground-penetrating radar on the surface of Mars and will be used to determine how different layers of the Martian surface formed over time. The data could help pave the way for future sensors that hunt for subsurface water ice deposits.
Also with an eye on future Red Planet explorations, the Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE) technology demonstration will attempt to manufacture oxygen out of thin air -- the Red Planet's tenuous and mostly carbon dioxide atmosphere. The rover's Mars Environmental Dynamics Analyzer (MEDA) instrument, which has sensors on the mast and chassis, will provide key information about present-day Mars weather, climate, and dust.
Currently attached to the belly of Perseverance, the diminutive Ingenuity Mars Helicopter is a technology demonstration that will attempt the first powered, controlled flight on another planet.
Project engineers and scientists will now put Perseverance through its paces, testing every instrument, subsystem, and subroutine over the next month or two. Only then will they deploy the helicopter to the surface for the flight test phase. If successful, Ingenuity could add an aerial dimension to exploration of the Red Planet in which such helicopters serve as a scouts or make deliveries for future astronauts away from their base.

Once Ingenuity's test flights are complete, the rover's search for evidence of ancient microbial life will begin in earnest.
"Perseverance is more than a rover, and more than this amazing collection of men and women that built it and got us here," said John McNamee, project manager of the Mars 2020 Perseverance rover mission at JPL. "It is even more than the 10.9 million people who signed up to be part of our mission. This mission is about what humans can achieve when they persevere. We made it this far. Now, watch us go."

More About the Mission

A primary objective for Perseverance's mission on Mars is astrobiology research, including the search for signs of ancient microbial life. The rover will characterize the planet's geology and past climate and be the first mission to collect and cache Martian rock and regolith, paving the way for human exploration of the Red Planet.
Subsequent NASA missions, in cooperation with ESA, will send spacecraft to Mars to collect these cached samples from the surface and return them to Earth for in-depth analysis.
The Mars 2020 Perseverance mission is part of NASA's Moon to Mars exploration approach, which includes Artemis missions to the Moon that will help prepare for human exploration of the Red Planet.
JPL, a division of Caltech in Pasadena, California, manages the Mars 2020 Perseverance mission and the Ingenuity Mars Helicopter technology demonstration for NASA.
For more about Perseverance:
https://mars.nasa.gov/mars2020/
and
https://nasa.gov/perseverance

- First black hole ever detected is more massive than we thought

Date: February 18, 2021
Source: International Centre for Radio Astronomy Research

New observations of the first black hole ever detected have led astronomers to question what they know about the Universe's most mysterious objects.
Published today in the journal *Science*, the research shows the system known as Cygnus X-1 contains the most massive stellar-mass black hole ever detected without the use of gravitational waves.
Cygnus X-1 is one of the closest black holes to Earth. It was discovered in 1964 when a pair of Geiger counters were carried on board a sub-orbital rocket launched from New Mexico.
The object was the focus of a famous scientific wager between physicists Stephen Hawking and Kip Thorne, with Hawking betting in 1974 that it was not a black hole. Hawking conceded the bet in 1990.
In this latest work, an international team of astronomers used the Very Long Baseline Array -- a continent-sized radio telescope made up of 10 dishes spread across the United States -- together with a clever technique to measure distances in space.
"If we can view the same object from different locations, we can calculate its distance away from us by measuring how far the object appears to move relative to the background," said lead researcher, Professor James Miller-Jones from Curtin University and the International Centre for Radio Astronomy Research (ICRAR).
"If you hold your finger out in front of your eyes and view it with one eye at a time, you'll notice your finger appears to jump from one spot to another. It's exactly the same principle."
"Over six days we observed a full orbit of the black hole and used observations taken of the same system with the same telescope array in 2011," Professor Miller-Jones said. "This method and our new measurements show the system is further away than previously thought, with a black hole that's significantly more massive."
Co-author Professor Ilya Mandel from Monash University and the ARC Centre of Excellence in Gravitational Wave Discovery (OzGrav) said the black hole is so massive it's actually challenging how astronomers thought they formed.
"Stars lose mass to their surrounding environment through stellar winds that blow away from their surface. But to make a black hole this heavy, we need to dial down the amount of mass that bright stars lose during their lifetimes" he said.
"The black hole in the Cygnus X-1 system began life as a star approximately 60 times the mass of the Sun and collapsed tens of thousands of years ago," he said. "Incredibly, it's orbiting its companion star -- a supergiant -- every five and a half days at just one-fifth of the distance between the Earth and the Sun.
"These new observations tell us the black hole is more than 20 times the mass of our Sun -- a 50 per cent increase on previous estimates."

Xueshan Zhao is a co-author on the paper and a PhD candidate studying at the National Astronomical Observatories -- part of the Chinese Academy of Sciences (NAOC) in Beijing.

"Using the updated measurements for the black hole's mass and its distance away from Earth, I was able to confirm that Cygnus X-1 is spinning incredibly quickly -- very close to the speed of light and faster than any other black hole found to date," she said.

"I'm at the beginning of my research career, so being a part of an international team and helping to refine the properties of the first black hole ever discovered has been a great opportunity."

Next year, the world's biggest radio telescope -- the Square Kilometre Array (SKA) -- will begin construction in Australia and South Africa.

"Studying black holes is like shining a light on the Universe's best kept secret -- it's a challenging but exciting area of research," Professor Miller-Jones said.

"As the next generation of telescopes comes online, their improved sensitivity reveals the Universe in increasingly more detail, leveraging decades of effort invested by scientists and research teams around the world to better understand the cosmos and the exotic and extreme objects that exist.

"It's a great time to be an astronomer."

- ❖ On the quest for other Earths

Date: February 17, 2021
Source: ETH Zurich

In the search for planets capable of sustaining life, an international research team with members from ETH has taken a significant step forward. As the researchers reported recently in the journal *Nature Communications*, they found signs of a Neptune-sized planet in the Alpha Centauri star system, a mere 4.4 light years away from Earth. This exoplanet is located in a zone that may offer suitable conditions for life. The team was able to collect data with unprecedented sensitivity, thus registering even very weak signals.

Earth is a disruptive factor

Thanks to the new process, the researchers have advanced one step closer to a major goal of exoplanet research: the discovery of Earth-like planets capable of supporting life. Direct imaging of planets delivers information about the composition of their atmospheres and possibly even signs of life. To date, however, direct measurements have mostly found exoplanets that are larger than Jupiter and orbit far away from very young host stars. In other words, these planets fall outside the habitable zone where liquid water could form. One reason that the search for Earth-like planets has so far proved fruitless is that it has been conducted in the near-infrared range, even though Earth-like planets that might have water are brightest in the mid-infrared range. Yet it is precisely in that range that measurements with normal telescopes are difficult, because that is where the Earth and its atmosphere are also at their brightest. This means the faint signals from exoplanets are lost in particularly strong background noise.

100 hours of observations

As reported in their study, the researchers have now been able to overcome this difficulty and take measurements in the mid-infrared range. They used the Very Large Telescope at the European Southern Observatory in Chile to examine Alpha Centauri stars A and B, logging nearly 100 hours over the course of a month. "Keeping the telescope pointed at the same star for such a long time is highly unusual," explains Anna Boehle, a postdoc in ETH Professor Sascha Quanz's group. As second author of the study, Boehle was heavily involved in evaluating the data. "We assessed more than five million images," she says.

To be able to detect the faint signals from potential planets, the researchers not only processed a huge volume of data, they also employed two sophisticated measurement techniques: one was to use a new deformable secondary telescope mirror, which made it possible to correct for distortions in the light coming through the Earth's atmosphere; and the other was to use a coronagraph to alternately block the light from each of the stars in turn at very short intervals. This let the scientists further reduce signal noise while examining the surroundings of both stars.

Signs of a planet

"Our findings indicate that in principle, this process enables us to discover smaller terrestrial planets capable of hosting life," Boehle explains, "and it represents a clear improvement over previous observation methods." Indeed, in their data the researchers found a light signal that may originate from a Neptune-sized planet. Boehle says, "Whether or not this signal is actually from a planet requires further study. To that end, we plan to

combine the infrared measurements with other measurement methods."

- The smallest galaxies in our universe bring more about dark matter to light

Date: February 16, 2021
Source: Tohoku University

Our universe is dominated by a mysterious matter known as dark matter. Its name comes from the fact that dark matter does not absorb, reflect or emit electromagnetic radiation, making it difficult to detect.

Now, a team of researchers has investigated the strength of dark matter scattered across the smallest galaxies in the universe using stellar kinematics.

"We discovered that the strength of dark matter is quite small, suggesting that dark matter does not easily scatter together," said professor Kohei Hayashi, lead author of the study.

Much is unknown about dark matter, but theoretical and experimental research, from particle physics to astronomy, are elucidating more about it little by little.

One prominent theory surrounding dark matter is the "self-interacting dark matter (SIDM) theory." It purports that dark matter distributions in galactic centres become less dense because of the self-scattering of dark matter.

However, supernova explosions, which occur toward the end of a massive star's life, can also form less dense distributions. This makes it challenging to distinguish whether it is the supernova explosion or the nature of dark matter that causes a less dense distribution of dark matter.

To clarify this, Hayashi and his team focused on ultra-faint dwarf galaxies. Here a few stars exist, rendering the influences of supernova explosions negligible.

Their findings showed that dark matter is dense at the centre of the galaxy, challenging the basic premise of SIDM. Images from the dwarf galaxy Segue 1 revealed high dark matter density at the centre of the galaxy, and that scattering is limited.

"Our study showed how useful stellar kinematics in ultra-faint dwarf galaxies are for testing existing theories on dark matter," noted Hayashi. "Further observations using next-generation wide-field spectroscopic surveys with the Subaru Prime Focus Spectrograph, will maximize the chance of obtaining dark matter's smoking gun."

- NASA's TESS discovers new worlds in a river of young stars

Date: February 12, 2021
Source: NASA/Goddard Space Flight Centre

Using observations from NASA's Transiting Exoplanet Survey Satellite (TESS), an international team of astronomers has discovered a trio of hot worlds larger than Earth orbiting a much younger version of our Sun called TOI 451. The system resides in the recently discovered Pisces-Eridanus stream, a collection of stars less than 3% the age of our solar system that stretches across one-third of the sky.

The planets were discovered in TESS images taken between October and December 2018. Follow-up studies of TOI 451 and its planets included observations made in 2019 and 2020 using NASA's Spitzer Space Telescope, which has since been retired, as well as many ground-based facilities. Archival infrared data from NASA's Near-Earth Object Wide-Field Infrared Survey Explorer (NEOWISE) satellite -- collected between 2009 and 2011 under its previous moniker, WISE -- suggests the system retains a cool disk of dust and rocky debris. Other observations show that TOI 451 likely has two distant stellar companions circling each other far beyond the planets.

"This system checks a lot of boxes for astronomers," said Elisabeth Newton, an assistant professor of physics and astronomy at Dartmouth College in Hanover, New Hampshire, who led the research. "It's only 120 million years old and just 400 light-years away, allowing detailed observations of this young planetary system. And because there are three planets between two- and four-times Earth's size, they make especially promising targets for testing theories about how planetary atmospheres evolve."

A paper reporting the findings was published on Jan. 14 in *The Astronomical Journal* and is available online.

Stellar streams form when the gravity of our Milky Way galaxy tears apart star clusters or dwarf galaxies. The individual stars move out along the cluster's original orbit, forming an elongated group that gradually disperses.

In 2019, a team led by Stefan Meingast at the University of Vienna used data from the European Space Agency's Gaia mission to discover the Pisces-Eridanus stream, named for the constellations containing the greatest concentrations of stars. Stretching across 14 constellations, the stream is about 1,300 light-

years long. However, the age initially determined for the stream was much older than we now think.

Later in 2019, researchers led by Jason Curtis at Columbia University in New York City analysed TESS data for dozens of stream members. Younger stars spin faster than their older counterparts do, and they also tend to have prominent star spots -- darker, cooler regions like sunspots. As these spots rotate in and out of our view, they can produce slight variations in a star's brightness that TESS can measure.

The TESS measurements revealed overwhelming evidence of star spots and rapid rotation among the stream's stars. Based on this result, Curtis and his colleagues found that the stream was only 120 million years old -- similar to the famous Pleiades cluster and eight times younger than previous estimates. The mass, youth, and proximity of the Pisces-Eridanus stream make it an exciting fundamental laboratory for studying star and planet formation and evolution.

"Thanks to TESS's nearly all-sky coverage, measurements that could support a search for planets orbiting members of this stream were already available to us when the stream was identified," said Jessie Christiansen, a co-author of the paper and the deputy science lead at the NASA Exoplanet Archive, a facility for researching worlds beyond our solar system managed by Caltech in Pasadena, California. "TESS data will continue to allow us to push the limits of what we know about exoplanets and their systems for years to come."

The young star TOI 451, better known to astronomers as CD-38 1467, lies about 400 light-years away in the constellation Eridanus. It has 95% of our Sun's mass, but it is 12% smaller, slightly cooler, and emits 35% less energy. TOI 451 rotates every 5.1 days, which is more than five times faster than the Sun.

TESS spots new worlds by looking for transits, the slight, regular dimmings that occur when a planet passes in front of its star from our perspective. Transits from all three planets are evident in the TESS data.

Newton's team obtained measurements from Spitzer that supported the TESS findings and helped to rule out possible alternative explanations. Additional follow-up observations came from Las Cumbres Observatory -- a global telescope network headquartered in Goleta, California -- and the Perth Exoplanet Survey Telescope in Australia.

Even TOI 451's most distant planet orbits three times closer than Mercury ever approaches to the Sun, so all of these worlds are quite hot and inhospitable to life as we know it. Temperature estimates range from about 2,200 degrees Fahrenheit (1,200 degrees Celsius) for the innermost planet to about 840 F (450 C) for the outermost one.

TOI 451 b orbits every 1.9 days, is about 1.9 times Earth's size, and its estimated mass ranges from two to 12 times Earth's. The next planet out, TOI 451 c, completes an orbit every 9.2 days, is about three times larger than Earth, and holds between three- and 16-times Earth's mass. The farthest and largest world, TOI 451 d, circles the star every 16 days, is four times the size of our planet, and weighs between four and 19 Earth masses.

Astronomers expect planets as big as these to retain much of their atmospheres despite the intense heat from their nearby star. Different theories of how atmospheres evolve by the time a planetary system reaches TOI 451's age predict a wide range of properties. Observing starlight passing through the atmospheres of these planets provides an opportunity to study this phase of development and could aid in constraining current models.

"By measuring starlight penetrating a planet's atmosphere at different wavelengths, we can infer its chemical composition and the presence of clouds or high-altitude hazes," said Elisa Quintana, an astrophysicist at NASA's Goddard Space Flight Centre in Greenbelt, Maryland. "TOI 451's planets offer excellent targets for such studies with Hubble and the upcoming James Webb Space Telescope."

Observations from WISE show that the system is unusually bright in infrared light, which is invisible to human eyes, at wavelengths of 12 and 24 micrometres. This suggests the presence of a debris disk, where rocky asteroid-like bodies collide and grind themselves to dust. While Newton and her team cannot determine the extent of the disk, they envision it as a diffuse ring of rock and dust cantered about as far from the star as Jupiter is from our Sun.

The researchers also investigated a faint neighbouring star that appears about two pixels away from TOI 451 in TESS images. Based on Gaia data, Newton's team determined this star to be a gravitationally

bound companion located so far from TOI 451 that its light takes 27 days to get there. In fact, the researchers think the companion is likely a binary system of two M-type dwarf stars, each with about 45% of the Sun's mass and emitting only 2% of its energy.
TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA's Goddard Space Flight Centre. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA's Ames Research Centre in California's Silicon Valley; the Centre for Astrophysics | Harvard & Smithsonian in Cambridge, Massachusetts; MIT's Lincoln Laboratory; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes, and observatories worldwide are participants in the mission.
NASA's Jet Propulsion Laboratory in Southern California manages NEOWISE for NASA's Science Mission Directorate in Washington. Ball Aerospace & Technologies Corp. of Boulder, Colorado, built the spacecraft. Science data processing takes place at IPAC at Caltech in Pasadena. Caltech manages JPL for NASA.

- Rare blast's remains discovered in Milky Way's centre

Date: February 8, 2021
Source: NASA/Marshall Space Flight Centre

Milky Way Galaxy (stock image).
Credit: © mandritoiu / stock.adobe.com

Astronomers may have found our galaxy's first example of an unusual kind of stellar explosion. This discovery, made with NASA's Chandra X-ray Observatory, adds to the understanding of how some stars shatter and seed the universe with elements critical for life on Earth.
This intriguing object, located near the centre of the Milky Way, is a supernova remnant called Sagittarius A East, or Sgr A East for short. Based on Chandra data, astronomers previously classified the object as the remains of a massive star that exploded as a supernova, one of many kinds of exploded stars that scientists have catalogued.
Using longer Chandra observations, a team of astronomers has now instead concluded that the object is left over from a different type of supernova. It is the explosion of a white dwarf, a shrunken stellar ember from a fuel-depleted star like our Sun. When a white dwarf pulls too much material from a companion star or merges with another white dwarf, the white dwarf is destroyed, accompanied by a stunning flash of light. Astronomers use these "Type Ia supernovae" because most of them mete out almost the same amount of light every time no matter where they are located. This allows scientists to use them to accurately measure distances across space and study the expansion of the universe.
Data from Chandra have revealed that Sgr A East, however, did not come from an ordinary Type Ia. Instead, it appears that it belongs to a special group of supernovae that produce different relative amounts of elements than traditional Type Ias do, and less powerful explosions. This subset is referred to as "Type Iax," a potentially important member of the supernova family.
"While we've found Type Iax supernovae in other galaxies, we haven't identified evidence for one in the Milky Way until now," said Ping Zhou of Nanjing University in China, who led the new study while at the University of Amsterdam. "This discovery is important for getting a handle of the myriad ways white dwarfs explode."
The explosions of white dwarfs is one of the most important sources in the universe of elements like iron, nickel, and chromium. The only place that scientists know these elements can be created is inside the nuclear furnace of stars or when they explode.
"This result shows us the diversity of types and causes of white dwarf explosions, and the different ways that they make these essential elements," said co-author Shing-Chi Leung of Caltech in Pasadena, California. "If we're right about the identity of this supernova's remains, it would be the nearest known example to Earth."
Astronomers are still debating the cause of Type Iax supernova explosions, but the leading theory is that they involve thermonuclear reactions that travel much more slowly through the star than in Type Ia

supernovae. This relatively slow walk of the blast leads to weaker explosions and, hence, different amounts of elements produced in the explosion. It is also possible that part of the white dwarf is left behind.
Sgr A East is located very close to Sagittarius A*, the supermassive black hole in the centre of our Milky Way galaxy, and likely intersects with the disk of material surrounding the black hole. The team was able to use Chandra observations targeting the supermassive black hole and the region around it for a total of about 35 days to study Sgr A East and find the unusual pattern of elements in the X-ray data. The Chandra results agree with computer models predicting a white dwarf that has undergone slow-moving nuclear reactions, making it a strong candidate for a Type Iax supernova remnant.
"This supernova remnant is in the background of many Chandra images of our galaxy's supermassive black hole taken over the last 20 years," said Zhiyuan Li, also of Nanjing University. "We finally may have worked out what this object is and how it came to be."
In other galaxies, scientists observe that Type Iax supernovae occur at a rate that is about one third that of Type Ia supernovae. In the Milky Way, there have been three confirmed Type Ia supernova remnants and two candidates that are younger than 2,000 years, corresponding to an age when remnants are still relatively bright before fading later. If Sgr A East is younger than 2,000 years and resulted from a Type Iax supernova, this study suggests that our galaxy is in alignment with respect to the relative numbers of Type Iax supernovae seen in other galaxies.
Along with the suggestion that Sgr A East is the remnant from the collapse of a massive star, previous studies have also pointed out that a normal Type Ia supernova had not been ruled out. The latest study conducted with this deep Chandra data argue against both the massive star and the normal Type Ia interpretations.
These results have been published today in *The Astrophysical Journal*, and a preprint is available online. The other co-authors of the paper are Ken'ichi Nomoto of The University of Tokyo in Japan, Jacco Vink of the University of Amsterdam in The Netherlands, and Yang Chen, also of Nanjing University.
NASA's Marshall Space Flight Centre manages the Chandra program. The Smithsonian Astrophysical Observatory's Chandra X-ray Centre controls science from Cambridge Massachusetts and flight operations from Burlington, Massachusetts.

- Portrait of young galaxy throws theory of galaxy formation on its head

Scientists peer 12 billion years into the past to reveal distant galaxy with an unexpected appearance
Date: February 11, 2021
Source: Cardiff University
Scientists have challenged our current understanding of how galaxies form by unveiling pictures of a young galaxy in the early life of the Universe which appears surprisingly mature.
The galaxy, dubbed ALESS 073.1, appears to have all of the features expected of a much more mature galaxy and has led the team of scientists to question how it grew so fast.
The new research has been published today in *Science*.
Galaxies come in a variety of shapes, sizes and colours, and are made up of different components such as rotating disks, spiral arms, and "bulges."
A major goal of present-day astronomy is understanding why different galaxies look the way they are today and when their different components formed.
The team, led by scientists at Cardiff University, used the Atacama Large Millimetre/submillimetre Array (ALMA) telescope as a 'time machine' to peer into the remote past, revealing how ALESS 073.1 looked just 1.2 billion years after the Big Bang.
Because the light emitted from the galaxy took billions of years to reach our telescopes on Earth, the team were able to explore how the galaxy looked during its infancy and determine how it was initially formed.
The result was one of the sharpest, direct images of a primordial galaxy ever produced which allowed the team to undertake a detailed study of its internal structure.
"We discovered that a massive bulge, a regular rotating disk, and possibly spiral arms were already in place in this galaxy when the Universe was just 10% of its current age," said lead author of the study Dr Federico Lelli, who undertook the work at Cardiff University's School of Physics and Astronomy.
"In other words, this galaxy looks like a grown adult, but it should be just a little child."

Co-author of the study Dr Timothy Davis, from the School of Physics and Astronomy, said: "This spectacular discovery challenges our current understanding of how galaxies form because we believed these features only arose in "mature" galaxies, not in young ones."

One key feature of a galaxy is the presence of a so-called bulge -- a tightly packed group of stars usually situated within the centre of the galaxy.

It was believed that massive bulges formed slowly by the merger of smaller galaxies or by specific processes that occurred within the galaxy itself; however, the kinematic properties of ALESS 073.1 have revealed that the formation of massive bulges can occur extremely fast -- around half of the stars in the galaxy were shown to be in a bulge.

Similarly, some mature galaxies, like our own Milky Way, have been known to have spiral arms extending from their central parts, giving them a distinctive spiral shape.

Similar features were also unexpectedly spotted in ALESS 073.1, much to the team's amazement, as early galaxies are generally thought to be chaotic and turbulent rather than having regular, well-organized structures like spiral arms.

"A galaxy like ALESS 073.1 just defies our understanding of galaxy formation," concluded Dr Lelli.

- ❖ Vaporised crusts of Earth-like planets found in dying stars

Date: February 11, 2021
Source: University of Warwick

Remnants of planets with Earth-like crusts have been discovered in the atmospheres of four nearby white dwarf stars by University of Warwick astronomers, offering a glimpse of the planets that may have once orbited them up to billions of years ago.

These crusts are from the outer layers of rocky planets similar to Earth and Mars and could give astronomers greater insights into the chemistry of the planets that these dying stars once hosted.

The discovery is reported today (11 February) in the journal *Nature Astronomy* and includes one of the oldest planetary systems seen by astronomers so far.

The University of Warwick-led team were analysing data from the European Space Agency's Gaia telescope of over 1,000 nearby white dwarf stars when they came across an unusual signal from one particular white dwarf. The researchers at the University of Warwick received funding from the European Research Council and the Science and Technology Facilities Council (STFC).

They used spectroscopy to analyse the light from the star at different wavelengths, which allows them to detect when elements in the star's atmosphere are absorbing light at different colours and determine what elements those are and how much is present. They also inspected the 30,000 white dwarf spectra from the Sloan Digital Sky Survey published over the last 20 years.

The signal matched the wavelength of lithium and the astronomers soon discovered three more white dwarfs with the same signal, one of which was also observed with potassium in its atmosphere. By comparing the amount of lithium and potassium with the other elements they detected -- sodium and calcium -- they found that the ratio of elements matched the chemical composition of the crust of rocky planets like Earth and Mars, if those crusts and been vaporised and mixed within the gaseous outer layers of the star for 2 million years.

Lead author Dr Mark Hollands from the University of Warwick's Department of Physics said: "In the past, we've seen all sorts of things like mantle and core material, but we've not had a definitive detection of planetary crust. Lithium and potassium are good indicators of crust material, they are not present in high concentrations in the mantle or core.

"Now we know what chemical signature to look for to detect these elements, we have the opportunity to look at a huge number of white dwarfs and find more of these. Then we can look at the distribution of that signature and see how often we detect these planetary crusts and how that compares to our predictions."

The outer layers of the white dwarfs contain up to 300,000 gigatonnes of rocky debris, which includes up to 60 gigatonnes of lithium and 3,000 gigatonnes of potassium, equivalent to a 60km sphere of similar density to Earth's crust. The amount of crust material detected is similar in mass to that of the asteroids we see in our own solar system, leading the astronomers to believe that what they are seeing around all four stars is material broken off from a planet, rather than an entire planet itself.

Previous observations of white dwarfs have found evidence of material from the inner

core and mantle of planets, but no definitive evidence of crust material. Crust is a small fraction of a planet's mass and the elements detected in this study are only detectable when the star is very cool. White dwarfs are in the dying phase of their lifecycle, as they have burnt out their fuel and cool over billions of years. These four white dwarfs are thought to have burnt out their fuel up to 10 billion years ago and could be among the oldest white dwarfs formed in our galaxy.

Co-author Dr Pier-Emmanuel Tremblay from the University of Warwick said: "In one case, we are looking at planet formation around a star that was formed in the Galactic halo, 11-12.5 billion years ago, hence it must be one of the oldest planetary systems known so far. Another of these systems formed around a short-lived star that was initially more than four times the mass of the Sun, a record-breaking discovery delivering important constraints on how fast planets can form around their host stars."

Among the oldest of these white dwarfs, one is 70% more massive than average and so its huge mass would normally cause any material in its atmosphere to disappear relatively quickly, leading the astronomers to the conclusion that it must be replenishing the crust material from a surrounding debris disc. Furthermore, the astronomers detected more infrared light than expected for the white dwarf alone, which indicates a disc being heated by its star and then re-radiated at longer wavelengths.

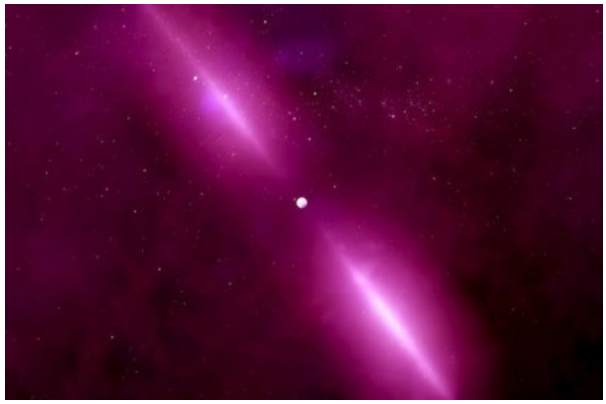
Dr Hollands adds: "As we understand it, rocky planet formation happens in a similar way in different planetary systems. Initially, they are formed from similar material composition to the star, but over time those materials separate and you end up with different chemical compositions in different parts of the planets. We can see that at some point that these objects have undergone differentiation, where the composition is different to the starting composition of the star.

"It is now well understood that most normal stars like the Sun harbour planets, but now there's the opportunity to look at the frequency of different types of material as well."

True identity of mysterious gamma-ray source revealed

Date: February 3, 2021

Source: University of Manchester



Neutron star illustration (stock image; elements furnished by NASA).
Credit: © Artsiom P / stock.adobe.com

An international research team including members from The University of Manchester has shown that a rapidly rotating neutron star is at the core of a celestial object now known as PSR J2039-5617

The international collaboration used novel data analysis methods and the enormous computing power of the citizen science project Einstein@Home to track down the neutron star's faint gamma-ray pulsations in data from NASA's Fermi Space Telescope. Their results show that the pulsar is in orbit with a stellar companion about a sixth of the mass of our Sun. The pulsar is slowly but surely evaporating this star. The team also found that the companion's orbit varies slightly and unpredictably over time. Using their search method, they expect to find more such systems with Einstein@Home in the future.

Searching for the so-called 'Spider' pulsar systems -- rapidly spinning neutron stars whose high-energy outflows are destroying their binary companion star, required 10 years of precise data. The pulsars have been given arachnid names of 'Black widows' or 'Redbacks', after species of spider where the females have been seen to kill the smaller males after mating.

New research published in, *Monthly Notices of the Royal Astronomical Society,* details how researchers found a neutron star rotating 377 times a second in an exotic binary system using data from NASA's Fermi Space Telescope.

The astronomer's findings were uniquely boosted by the Einstein@Home project, a network of thousands of civilian volunteers lending their home computing power to the efforts of the Fermi Telescope's work.

The group's search required combing very finely through the data in order not to miss any possible signals. The computing power required is enormous. The search would have

taken 500 years to complete on a single computer core. By using a part of the Einstein@Home resources it was done in 2 months.
With the computing power donated by the Einstein@Home volunteers, the team discovered gamma-ray pulsations from the rapidly rotating neutron star. This gamma-ray pulsar, now known as J2039-5617, rotates about 377 times each second.
"It had been suspected for years that there is a pulsar, a rapidly rotating neutron star, at the heart of the source we now know as PSR J2039-5617," says Lars Nieder, a PhD student at the Max Planck Institute for Gravitational Physics (Albert Einstein Institute; AEI) in Hannover. "But it was only possible to lift the veil and discover the gamma-ray pulsations with the computing power donated by tens of thousands of volunteers to Einstein@Home," he adds.
The celestial object has been known since 2014 as a source of X-rays, gamma rays, and light. All evidence obtained so far pointed at a rapidly rotating neutron star in orbit with a light-weight star being at the heart of the source. But clear proof was missing.
The first step to solving this riddle were new observations of the stellar companion with optical telescopes. They provided precise knowledge about the binary system without which a gamma-ray pulsar search (even with Einstein@Home's huge computing power) would be unfeasible.
The system's brightness varies during an orbital period depending on which side of the neutron star's companion is facing the Earth. "For J2039-5617, there are two main processes at work," explains Dr. Colin Clark from Jodrell Bank Centre for Astrophysics, lead author of the study. "The pulsar heats up one side of the light-weight companion, which appears brighter and more bluish. Additionally, the companion is distorted by the pulsar's gravitational pull causing the apparent size of the star to vary over the orbit. These observations allowed the team to get the most precise measurement possible of the binary star's 5.5-hour orbital period, as well as other properties of the system."
With this information and the precise sky position from Gaia data, the team used the aggregated computing power of the distributed volunteer computing project Einstein@Home for a new search of about 10 years of archival observations of NASA's Fermi Gamma-ray Space Telescope. Improving on earlier methods they had developed for this purpose, they enlisted the help of tens of thousands of volunteers to search Fermi data for periodic pulsations in the gamma-ray photons registered by the Large Area Telescope onboard the space telescope. The volunteers donated idle compute cycles on their computers' CPUs and GPUs to Einstein@Home.
The new knowledge of the frequency of the gamma-ray pulsations also allowed collaborators to detect radio pulsations in archival data from the Parkes radio telescope. Their results, also published in *Monthly Notices of the Royal Astronomical Society,* show that the pulsar's radio emission is often eclipsed by material that has been blown off the companion star by its nearby Redback pulsar.

- ❖ Scientist proposes a new timeline for Mars terrains

Updated models predict that NASA's Perseverance rover will encounter more ancient surfaces
Date: February 11, 2021
Source: Southwest Research Institute
A Southwest Research Institute scientist has updated Mars chronology models to find that terrains shaped by ancient water activity on the planet's surface may be hundreds of millions of years older than previously thought. This new chronology for Mars, based on the latest dynamical models for the formation and evolution of the solar system, is particularly significant as the days count down until NASA's Mars 2020 Perseverance rover lands on the Red Planet on February 18, 2021.
Unlike on Earth, where terrains are commonly dated using natural radioactivity of rocks, scientists have largely constrained the chronology of Mars by counting impact craters on its surface.
"The idea behind crater dating is not rocket science; the more craters, the older the surface," says SwRI's Dr. Simone Marchi, who published a paper about these findings accepted for publication in *The Astronomical Journal*. "But the devil is in the details. Craters form when asteroids and comets strike the surface. The rate of these cosmic crashes over the eons is uncertain, hampering our ability to convert crater numbers to terrain ages. I took a fresh look at this and built on recent developments in the way we

understand the earliest evolution of the solar system."
Scientists have used radiometric ages of precious lunar rocks brought back by the Apollo missions to calibrate a lunar crater chronology. This lunar chronology is then extrapolated to Mars, and this is where things get tangled with the earliest evolution of the solar system. Our understanding of the time evolution of lunar and Martian impact rates has greatly improved in recent years. The present model improves upon how the critical Moon-to-Mars extrapolations are done.
"For this paper, I looked particularly at the Jezero Crater because that is the landing site for the Mars 2020 Perseverance rover," Marchi said. "These surfaces could have formed over 3 billion years ago, as much as 500 million years older than previously thought. NASA plans to have Perseverance gather and package surface samples that can be collected by a future mission for return to Earth for radiometric dating. That could provide vital ground-truth data to better calibrate our chronology models."
Jezero Crater has a diameter of about 30 miles located within the 750-mile-wide Isidis Basin, created by an earlier impact. The latter cut a wide portion of the Borealis Basin's rim, perhaps the largest and oldest impact basin on Mars. This coincidence of nested craters is of particular interest as samples from these terrains may return information about the timing of these consecutive impacts.
Furthermore, Jezero Crater hosts clay-rich terrains and a fluvial delta, indications that the crater once hosted a lake. This makes the Jezero Crater an ideal place to fulfil the Mars 2020 mission's science goal of studying a potentially habitable environment that may still preserve signs of past life. As such, understanding the timeline of these surfaces is particularly important.
The new model also provides a revised age for Isidis Basin, now estimated to be 4-4.2 billion years old, providing an upper limit for the formation of Jezero Crater and water activity at this location on Mars.

- Astronomers uncover mysterious origins of 'super-Earths'

Study shows super-Earths are not leftovers of mini-Neptune's, challenging our understanding of planetary formation
Date: February 10, 2021
Source: McGill University

Mini-Neptune's and super-Earths up to four times the size of our own are the most common exoplanets orbiting stars beyond our solar system. Until now, super-Earths were thought to be the rocky cores of mini-Neptune's whose gassy atmospheres were blown away. In a new study published in *The Astrophysical Journal*, astronomers from McGill University show that some of these exoplanets never had gaseous atmospheres to begin with, shedding new light on their mysterious origins.
From observations, we know about 30 to 50 percent of host stars have one or the other, and the two populations appear in about equal proportion. But where did they come from? One theory is that most exoplanets are born as mini-Neptune's but some are stripped of their gas shells by radiation from host stars, leaving behind only a dense, rocky core. This theory predicts that our Galaxy has very few Earth-sized and smaller exoplanets known as Earths and mini-Earths. However, recent observations show this may not be the case.
To find out more, the astronomers used a simulation to track the evolution of these mysterious exoplanets. The model used thermodynamic calculations based on how massive their rocky cores are, how far they are from their host stars, and how hot the surrounding gas is.
"Contrary to previous theories, our study shows that some exoplanets can never build gaseous atmospheres to begin with," says co-author Eve Lee, Assistant Professor in the Department of Physics at McGill University and the McGill Space Institute.
The findings suggest that not all super-Earths are remnants of mini-Neptune's. Rather, the exoplanets were formed by a single distribution of rocks, born in a spinning disk of gas and dust around host stars. "Some of the rocks grew gas shells, while others emerged and remained rocky super-Earths," she says.

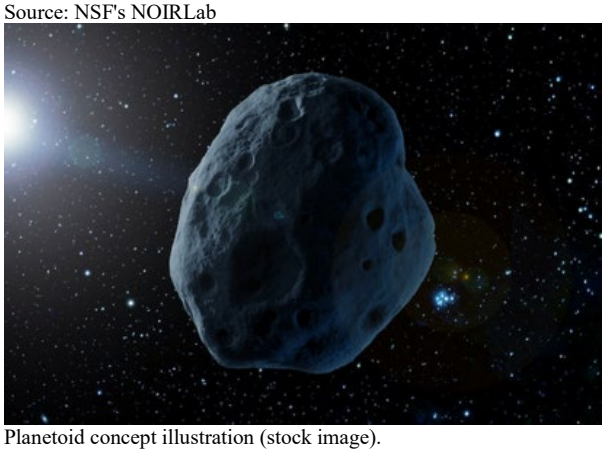
How mini-Neptune's and super-Earths are born

Planets are thought to form in a spinning disk of gas and dust around stars. Rocks larger than the moon have enough gravitational pull to attract surrounding gas to form a shell around its core. Over time this shell of gas cools down and shrinks, creating space for more surrounding gas to be pulled in, and causing the exoplanet to grow. Once the entire shell cools down to the same temperature as

the surrounding nebular gas, the shell can no longer shrink and growth stops.
For smaller cores, this shell is tiny, so they remain rocky exoplanets. The distinction between super-Earths and mini-Neptune's comes about from the ability of these rocks to grow and retain gas shells.
"Our findings help explain the origin of the two populations of exoplanets, and perhaps their prevalence" says Lee. "Using the theory proposed in the study, we could eventually decipher how common rocky exoplanets like Earths and mini-Earths may be."

- Astronomers confirm solar system's most distant known object is indeed Farfarout

Date: February 10, 2021
Source: NSF's NOIRLab



Planetoid concept illustration (stock image).
Credit: © Artsiom P / stock.adobe.com

With the help of the international Gemini Observatory, a Program of NSF's NOIRLab, and other ground-based telescopes, astronomers have confirmed that a faint object discovered in 2018 and nicknamed "Farfarout" is indeed the most distant object yet found in our Solar System. The object has just received its designation from the International Astronomical Union.
Farfarout was first spotted in January 2018 by the Subaru Telescope, located on Maunakea in Hawai'i. Its discoverers could tell it was very far away, but they weren't sure exactly how far. They needed more observations.
"At that time we did not know the object's orbit as we only had the Subaru discovery observations over 24 hours, but it takes years of observations to get an object's orbit around the Sun," explained co-discoverer Scott Sheppard of the Carnegie Institution for Science. "All we knew was that the object appeared to be very distant at the time of discovery."
Sheppard and his colleagues, David Tholen of the University of Hawai'i and Chad Trujillo of Northern Arizona University, spent the next few years tracking the object with the Gemini North telescope (also on Maunakea in Hawai'i) and the Carnegie Institution for Science's Magellan Telescopes in Chile to determine its orbit. They have now confirmed that Farfarout currently lies 132 astronomical units (au) from the Sun, which is 132 times farther from the Sun than Earth is. (For comparison, Pluto is 39 au from the Sun, on average.)
Farfarout is even more remote than the previous Solar System distance record-holder, which was discovered by the same team and nicknamed "Farout." Provisionally designated 2018 VG_{18}, Farout is 124 au from the Sun. However, the orbit of Farfarout is quite elongated, taking it 175 au from the Sun at its farthest point and around 27 au at its closest, which is inside the orbit of Neptune. Because its orbit crosses Neptune's, Farfarout could provide insights into the history of the outer Solar System.
"Farfarout was likely thrown into the outer Solar System by getting too close to Neptune in the distant past," said Trujillo. "Farfarout will likely interact with Neptune again in the future since their orbits still intersect."
Farfarout is very faint. Based on its brightness and distance from the Sun, the team estimates it to be about 400 kilometres (250 miles) across, putting it at the low end of possibly being designated a dwarf planet by the International Astronomical Union (IAU).
The IAU's Minor Planet Centre in Massachusetts announced today that it has given Farfarout the provisional designation 2018 AG_{37}. The Solar System's most distant known member will receive an official name after more observations are gathered and its orbit becomes even more refined in the coming years.
"Farfarout takes a millennium to go around the Sun once," said Tholen. "Because of this, it moves very slowly across the sky, requiring several years of observations to precisely determine its trajectory."
Farfarout's discoverers are confident that even more distant objects remain to be discovered on the outskirts of the Solar System, and that its distance record might not stand for long.
"The discovery of Farfarout shows our increasing ability to map the outer Solar System and observe farther and farther towards the fringes of our Solar System," said Sheppard. "Only with the advancements in the last few years of large digital cameras on very large telescopes has it been possible to

efficiently discover very distant objects like Farfarout. Even though some of these distant objects are quite large -- the size of dwarf planets -- they are very faint because of their extreme distances from the Sun. Farfarout is just the tip of the iceberg of objects in the very distant Solar System."

- A new way to look for life-sustaining planets

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It is now possible to capture images of planets that could potentially sustain life around nearby stars, thanks to advances reported by an international team of astronomers in the journal *Nature Communications.*

Using a newly developed system for mid-infrared exoplanet imaging, in combination with a very long observation time, the study's authors say they can now use ground-based telescopes to directly capture images of planets about three times the size of Earth within the habitable zones of nearby stars.

Efforts to directly image exoplanets -- planets outside our solar system -- have been hamstrung by technological limitations, resulting in a bias toward the detection of easier-to-see planets that are much larger than Jupiter and are located around very young stars and far outside the habitable zone -- the "sweet spot" in which a planet can sustain liquid water. If astronomers want to find alien life, they need to look elsewhere.

"If we want to find planets with conditions suitable for life as we know it, we have to look for rocky planets roughly the size of Earth, inside the habitable zones around older, sun-like stars," said the paper's first author, Kevin Wagner, a Sagan Fellow in NASA's Hubble Fellowship Program at the University of Arizona's Steward Observatory.

The method described in the paper provides more than a tenfold improvement over existing capabilities to directly observe exoplanets, Wagner said. Most studies on exoplanet imaging have looked in infrared wavelengths of less than 10 microns, stopping just short of the range of wavelengths where such planets shine the brightest, Wagner said.

"There is a good reason for that because the Earth itself is shining at you at those wavelengths," Wagner said. "Infrared emissions from the sky, the camera and the telescope itself are essentially drowning out your signal. But the good reason to focus on these wavelengths is that's where an Earth like planet in the habitable zone around a sun-like star is going to shine brightest."

The team used the Very Large Telescope, or VLT, of the European Southern Observatory in Chile to observe our closest neighbour star system: Alpha Centauri, just 4.4 light-years away. Alpha Centauri is a triple star system; it consists of two stars -- Alpha Centauri A and B -- that are similar to the sun in size and age and orbit each other as a binary system. The third star, Alpha Centauri C, better known as Proxima Centauri, is a much smaller red dwarf orbiting its two siblings at a great distance.

A planet not quite twice the size of Earth and orbiting in the habitable zone around Proxima Centauri has already been indirectly detected through observations of the star's radial velocity variation, or the tiny wobble a star exhibits under the tug of the unseen planet. According to the study's authors, Alpha Centauri A and B could host similar planets, but indirect detection methods are not yet sensitive enough to find rocky planets in their more widely separated habitable zones, Wagner explained.

"With direct imaging, we can now push beneath those detection limits for the first time," he said.

To boost the sensitivity of the imaging setup, the team used a so-called adaptive secondary telescope mirror that can correct for the distortion of the light by the Earth's atmosphere. In addition, the researchers used a starlight-blocking mask that they optimized for the mid-infrared light spectrum to block the light from one of the stars at a time. To enable observing both stars' habitable zones simultaneously, they also pioneered a new technique to switch back and forth between observing Alpha Centauri A and Alpha Centauri B very rapidly.

"We're moving one star on and one star off the coronagraph every tenth of a second," Wagner said. "That allows us to observe each star for half of the time, and, importantly, it also allows us to subtract one frame from the subsequent frame, which removes everything that is essentially just noise from the camera and the telescope."

Using this approach, the undesired starlight and "noise" -- unwanted signal from within the telescope and camera -- become essentially random background noise, possible to further reduce by stacking images and

subtracting the noise using specialized software.
Similar to the effect to noise-cancelling headphones, which allow soft music to be heard over a steady stream of unwanted jet engine noise, the technique allowed the team to remove as much of the unwanted noise as possible and detect the much fainter signals created by potential planet candidates inside the habitable zone.
The team observed the Alpha Centauri system for nearly 100 hours over the course of a month in 2019, collecting more than 5 million images. They collected about 7 terabytes of data, which they made publicly available at http://archive.eso.org .
"This is one of the first dedicated multi-night exoplanet imaging campaigns, in which we stacked all of the data we accumulated over nearly a month and used that to achieve our final sensitivity," Wagner said.
After removing so-called artefacts -- false signals created by the instrumentation and residual light from the coronagraph -- the final image revealed a light source designated as "C1" that could potentially hint at the presence of an exoplanet candidate inside the habitable zone.
"There is one-point source that looks like what we would expect a planet to look like, that we can't explain with any of the systematic error corrections," Wagner said. "We are not at the level of confidence to say we discovered a planet around Alpha Centauri, but there is a signal there that could be that with some subsequent verification."
Simulations of what planets within the data are likely to look like suggest that "C1" could be a Neptune- to Saturn-sized planet at a distance from Alpha Centauri A that is similar to the distance between the Earth and the sun, Wagner said. However, the authors clearly state that without subsequent verification, the possibility that C1 might be due to some unknown artefact caused by the instrument itself cannot be ruled out just yet.
Finding a potentially habitable planet within Alpha Centauri has been the goal of the initiative Breakthrough Watch/NEAR, which stands for New Earths in the Alpha Centauri Region. Breakthrough Watch is a global astronomical program looking for Earth like planets around nearby stars.
"We are very grateful to the Breakthrough Initiatives and ESO for their support in achieving another steppingstone towards the imaging of Earth like planets around our neighbour stars," said Markus Kasper, lead scientist of the NEAR project and a co-author on the paper.
The team intends to embark on another imaging campaign in a few years, in an attempt to catch this potential exoplanet in the Alpha Centauri system in a different location, and to see whether it would be consistent with what would be expected based on modelling its expected orbit. Further clues may come from follow-up observations using different methods.
The next-generation of extremely large telescopes, such as the Extremely Large Telescope of the European Southern Observatory, and the Giant Magellan Telescope, for which the University of Arizona produces the primary mirrors, are expected to be able to increase direct observations of nearby stars that might harbour planets in their habitable zones by a factor of 10, Wagner explained. Candidates to look at include Sirius, the brightest star in the night sky, and Tau Ceti, which hosts an indirectly observed planetary system that Wagner and his colleagues will try to directly image. "Making the capability demonstrated here a routine observing mode -- to be able to pick up heat signatures of planets orbiting within the habitable zones of nearby stars -- will be a game changer for the exploration of new worlds and for the search for life in the universe," said study co-author Daniel Apai, a UArizona associate professor of astronomy and planetary science who leads the NASA-funded Earths in Other Solar Systems program that partly supported the study.
Funding for NEAR was provided primarily by the Breakthrough Watch program and the European Southern Observatory (ESO). Breakthrough Watch is managed by the Breakthrough Initiatives, sponsored by the Breakthrough Foundation. Breakthrough Watch provided the instrument upgrades that made the observations possible, and ESO contributed the telescope time. For a full set of authors and institutions, and funding information, please see the research paper "Imaging low-mass planets within the habitable zone of Alpha; Centauri."
"Imaging Habitable-Zone Exoplanets Around Alpha Centauri," a video about this research by Kevin Wagner, is available at https://www.youtube.com/watch?v=Da2EMPuGu00&feature=youtu.be