South Downs Mercury

The monthly circular of South Downs Astronomical Society
Issue: 560 – January 7th 2022 Editor: Roger Burgess
Main Speaker 19:30 Lilian Hobbs The Lunar 100
The meeting will be accessible via Zoom

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

AGM this the one meeting during the year when the Trustees of the South Downs AS run the first half of the meeting. We have to appoint a new committee; anyone wishing to put their name forward can do so at the beginning of the meeting. If you know someone who might be able to serve on the committee, please ask them before nominating them. Being a committee member does not involve too much time or effort, the main thing is to be willing to take on some quite simple tasks, such as meet and greet at the main meetings, attend around six committee meetings each year.

- **Scientists' first take on asteroid dust from Japanese probe: Carbon rich, less lumpy than expected**

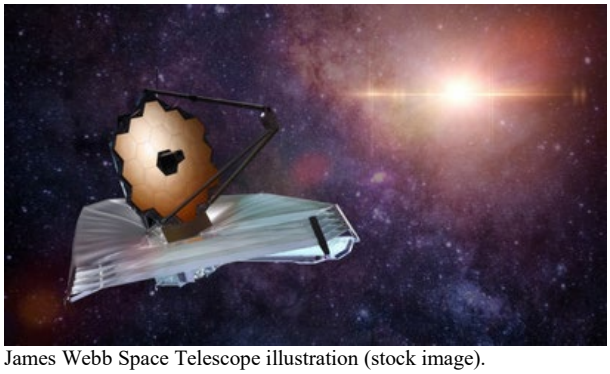
The five grams of Ryugu we got suggests it's made of the same stuff as the outer Sun
Laura Dobberstein Wed 22 Dec 2021 // 10:03 UTC

Researchers have published the first analyses of samples plucked from asteroid 162173 Ryugu by Japan's spacecraft Hayabusa2, revealing, for the first time, the physical properties and composition of a carbonaceous asteroid.
The 5.4g of asteroid sample collected from two surface locations on asteroid Ryugu landed in the South Australian outback a year ago before being shipped to Japan for investigation.
Some of the space pebbles went to NASA, but the bulk remained with Japan's Aerospace Exploration Agency JAXA and its scientists.
Astronomers have had high hopes for these samples, as they've never before had their hand on a dark and carbon-rich asteroid, or C-type, like Ryugu.
Studies of the samples physical properties revealed the sample resembled the spacecraft's on-site images of the flying space-rock and the collected material was representative of the asteroid as a whole.
Rich in water and organic matter, the ultra-dark material was a mix of elements rarely seen in meteorites that make it down to Earth, despite these C-type asteroids being the most common in the Solar System. The texture was also unusual, as it was uniformly fine and did not include the round chunky bits of melted minerals known as "chondrules".
Those characteristics suggest that Ryugu's parent body was a CI chondrite, a rare meteorite with a composition close to the stuff found in the Sun's outer shell.
"This demonstrates that Hayabusa2 has returned a sample whose parent body is definitively known and which will give us information about the early stages of the Solar System," said the authors of one of two papers published on Ryugu Tuesday in the journal *Nature Astronomy*. The authors made that assertion as the composition of CI chondrites are similar to the stuff theorized to have made up much of the Solar System when it was just formed. The results are exciting for supporters of the panspermia theory, which proposes that the building blocks for life are transported across the cosmos via comet or asteroid. C-type asteroids, in particular are thought to have seeded a young Earth with water and other essential life-supporting materials.
Indeed, scientists found organic molecules on the first comet humanity intercepted, Comet 67P/Churyumov-Gerasimenko. There's no reason known why chunks of comets housing organic materials wouldn't survive an impact and spread their cargo far and wide.
Of course, beyond the philosophical questions about humanity's maker, there's also a very real reason to study asteroids and that is that it would be really great to avoid having one hit the Earth and end all the fun and games here.

Scientists continue to dig in to the Ryugu samples and hope follow up studies might tell us how the Solar System evolved.
Comparisons of Ryugu to other asteroids are planned, to test for variations.
In addition to the dust and pebbles, the mission also produced what JAXA referred to as “the world's first sample return of a material in the gas state from deep space,” so we have more to look forward to than just solid matter.

- **NASA's Webb telescope launches to see first galaxies, distant worlds**

Date: December 25, 2021
Source: NASA



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

NASA's James Webb Space Telescope launched at 7:20 a.m. EST Saturday on an Ariane 5 rocket from Europe's Spaceport in French Guiana, South America.
A joint effort with ESA (European Space Agency) and the Canadian Space Agency, the Webb observatory is NASA's revolutionary flagship mission to seek the light from the first galaxies in the early universe and to explore our own solar system, as well as planets orbiting other stars, called exoplanets.
"The James Webb Space Telescope represents the ambition that NASA and our partners maintain to propel us forward into the future," said NASA Administrator Bill Nelson. "The promise of Webb is not what we know we will discover; it's what we don't yet understand or can't yet fathom about our universe. I can't wait to see what it uncovers!"
Ground teams began receiving telemetry data from Webb about five minutes after launch. The Arianespace Ariane 5 rocket performed as expected, separating from the observatory 27 minutes into the flight. The observatory was released at an altitude of approximately 75 miles (120 kilometres). Approximately 30 minutes after launch, Webb unfolded its solar array, and mission managers confirmed that the solar array was providing power to the observatory. After solar array deployment, mission operators will establish a communications link with the observatory via the Malindi ground station in Kenya, and ground control at the Space Telescope Science Institute in Baltimore will send the first commands to the spacecraft.
Engineers and ground controllers will conduct the first of three mid-course correction burns about 12 hours and 30 minutes after launch, firing Webb's thrusters to manoeuvre the spacecraft on an optimal trajectory toward its destination in orbit about 1 million miles from Earth.
"I want to congratulate the team on this incredible achievement -- Webb's launch marks a significant moment not only for NASA, but for thousands of people worldwide who dedicated their time and talent to this mission over the years," said Thomas Zurbuchen, associate administrator for the Science Mission Directorate at NASA Headquarters in Washington. "Webb's scientific promise is now closer than it ever has been. We are poised on the edge of a truly exciting time of discovery, of things we've never before seen or imagined."
The world's largest and most complex space science observatory will now begin six months of commissioning in space. At the end of commissioning, Webb will deliver its first images. Webb carries four state-of-the-art science instruments with highly sensitive infrared detectors of unprecedented resolution. Webb will study infrared light from celestial objects with much greater clarity than ever before. The premier mission is the scientific successor to NASA's iconic Hubble and Spitzer space telescopes, built to complement and further the scientific discoveries of these and other missions.
"The launch of the Webb Space Telescope is a pivotal moment -- this is just the beginning for the Webb mission," said Gregory L. Robinson, Webb's program director at NASA Headquarters. "Now we will watch Webb's highly anticipated and critical 29 days on the edge. When the spacecraft unfurls in space, Webb will undergo the most difficult and complex deployment sequence ever attempted in space. Once commissioning is complete, we will see awe-inspiring images that will capture our imagination."
The telescope's revolutionary technology will explore every phase of cosmic history -- from within our solar system to the most distant observable galaxies in the early universe, to everything in between. Webb will reveal new

and unexpected discoveries and help humanity understand the origins of the universe and our place in it.
NASA Headquarters oversees the mission for the agency's Science Mission Directorate. NASA's Goddard Space Flight Centre in Greenbelt, Maryland, manages Webb for the agency and oversees work on the mission performed by the Space Telescope Science Institute, Northrop Grumman, and other mission partners. In addition to Goddard, several NASA centres contributed to the project, including the agency's Johnson Space Centre in Houston, Jet Propulsion Laboratory in Southern California, Marshall Space Flight Centre in Huntsville, Alabama, Ames Research Centre in California's Silicon Valley, and others.
For more information about the Webb mission, visit:
https://webb.nasa.gov

- **Astronomers capture black hole eruption spanning 16 times the full Moon in the sky**

Date: December 22, 2021
Source: International Centre for Radio Astronomy Research
Astronomers have produced the most comprehensive image of radio emission from the nearest actively feeding supermassive black hole to Earth.
The emission is powered by a central black hole in the galaxy Centaurus A, about 12 million light years away.
As the black hole feeds on in-falling gas, it ejects material at near light-speed, causing 'radio bubbles' to grow over hundreds of millions of years.
When viewed from Earth, the eruption from Centaurus A now extends eight degrees across the sky -- the length of 16 full Moons laid side by side.
It was captured using the Murchison Widefield Array (MWA) telescope in outback Western Australia.
The research was published today in the journal *Nature Astronomy*.
Lead author Dr Benjamin McKinley, from the Curtin University node of the International Centre for Radio Astronomy Research (ICRAR), said the image reveals spectacular new details of the radio emission from the galaxy.
"These radio waves come from material being sucked into the supermassive black hole in the middle of the galaxy," he said.
"It forms a disc around the black hole, and as the matter gets ripped apart going close to the black hole, powerful jets form on either side of the disc, ejecting most of the material back out into space, to distances of probably more than a million light years.
"Previous radio observations could not handle the extreme brightness of the jets and details of the larger area surrounding the galaxy were distorted, but our new image overcomes these limitations."
Centaurus A is the closest radio galaxy to our own Milky Way.
"We can learn a lot from Centaurus A in particular, just because it is so close and we can see it in such detail," Dr McKinley said.
"Not just at radio wavelengths, but at all other wavelengths of light as well.
"In this research we've been able to combine the radio observations with optical and x-ray data, to help us better understand the physics of these supermassive black holes."
Astrophysicist Dr Massimo Gaspari, from Italy's National Institute for Astrophysics, said the study corroborated a novel theory known as 'Chaotic Cold Accretion' (CCA), which is emerging in different fields.
"In this model, clouds of cold gas condense in the galactic halo and rain down onto the central regions, feeding the supermassive black hole," he said.
"Triggered by this rain, the black hole vigorously reacts by launching energy back via radio jets that inflate the spectacular lobes we see in the MWA image. This study is one of the first to probe in such detail the multiphase CCA 'weather' over the full range of scales," Dr Gaspari concluded.
Dr McKinley said the galaxy appears brighter in the centre where it is more active and there is a lot of energy.
"Then it's fainter as you go out because the energy's been lost and things have settled down," he said.
"But there are interesting features where charged particles have re-accelerated and are interacting with strong magnetic fields."
MWA director Professor Steven Tingay said the research was possible because of the telescope's extremely wide field-of-view, superb radio-quiet location, and excellent sensitivity.
"The MWA is a precursor for the Square Kilometre Array (SKA) -- a global initiative to build the world's largest radio telescopes in Western Australia and South Africa," he said.

"The wide field of view and, as a consequence, the extraordinary amount of data we can collect, means that the discovery potential of every MWA observation is very high. This provides a fantastic step toward the even bigger SKA."

❖ Astronomers uncover largest group of rogue planets yet

Date: December 22, 2021
Source: ESO

Illustration of isolated planet (stock image).
Credit: © Zach Youngblood / stock.adobe.com

Rogue planets are elusive cosmic objects that have masses comparable to those of the planets in our Solar System but do not orbit a star, instead roaming freely on their own. Not many were known until now, but a team of astronomers, using data from several European Southern Observatory (ESO) telescopes and other facilities, have just discovered at least 70 new rogue planets in our galaxy. This is the largest group of rogue planets ever discovered, an important step towards understanding the origins and features of these mysterious galactic nomads.

"We did not know how many to expect and are excited to have found so many," says Núria Miret-Roig, an astronomer at the Laboratoire d'Astrophysique de Bordeaux, France and the University of Vienna, Austria, and the first author of the new study published today in *Nature Astronomy*.

Rogue planets, lurking far away from any star illuminating them, would normally be impossible to image. However, Miret-Roig and her team took advantage of the fact that, in the few million years after their formation, these planets are still hot enough to glow, making them directly detectable by sensitive cameras on large telescopes. They found at least 70 new rogue planets with masses comparable to Jupiter's in a star-forming region close to our Sun, in the Upper Scorpius and Ophiuchus constellations [1].

To spot so many rogue planets, the team used data spanning about 20 years from a number of telescopes on the ground and in space. "We measured the tiny motions, the colours and luminosities of tens of millions of sources in a large area of the sky," explains Miret-Roig. "These measurements allowed us to securely identify the faintest objects in this region, the rogue planets."

The team used observations from ESO's Very Large Telescope (VLT), the Visible and Infrared Survey Telescope for Astronomy (VISTA), the VLT Survey Telescope (VST) and the MPG/ESO 2.2-metre telescope located in Chile, along with other facilities. "The vast majority of our data come from ESO observatories, which were absolutely critical for this study. Their wide field of view and unique sensitivity were keys to our success," explains Hervé Bouy, an astronomer at the Laboratoire d'Astrophysique de Bordeaux, France, and project leader of the new research. "We used tens of thousands of wide-field images from ESO facilities, corresponding to hundreds of hours of observations, and literally tens of terabytes of data."

The team also used data from the European Space Agency's Gaia satellite, marking a huge success for the collaboration of ground- and space-based telescopes in the exploration and understanding of our Universe.

The study suggests there could be many more of these elusive, starless planets that we have yet to discover. "There could be several billions of these free-floating giant planets roaming freely in the Milky Way without a host star," Bouy explains.

By studying the newly found rogue planets, astronomers may find clues to how these mysterious objects form. Some scientists believe rogue planets can form from the collapse of a gas cloud that is too small to lead to the formation of a star, or that they could have been kicked out from their parent system. But which mechanism is more likely remains unknown.

Further advances in technology will be key to unlocking the mystery of these nomadic planets. The team hopes to continue to study them in greater detail with ESO's forthcoming Extremely Large Telescope (ELT), currently under construction in the Chilean Atacama Desert and due to start observations later this decade. "These objects are extremely faint and little can be done to study them with current facilities," says Bouy. "The ELT will be absolutely crucial to gathering more

information about most of the rogue planets we have found."

Note

[1] The exact number of rogue planets found by the team is hard to pin down because the observations don't allow the researchers to measure the masses of the probed objects. Objects with masses higher than about 13 times the mass of Jupiter are most likely not planets, so they cannot be included in the count. However, since the team didn't have values for the mass, they had to rely on studying the planets' brightness to provide an upper limit to the number of rogue planets observed. The brightness is, in turn, related to the age of the planets themselves, as the older the planet, the longer it has been cooling down and reducing in brightness. If the studied region is old, then the brightest objects in the sample are likely above 13 Jupiter masses, and below if the region is on the younger side. Given the uncertainty in the age of the study region, this method gives a rogue planet count of between 70 and 170.

❖ Earth and Mars were formed from inner Solar System material

International research team investigated the isotopic composition of rocky planets in the inner Solar System

Date: December 22, 2021
Source: University of Münster

Earth and Mars were formed from material that largely originated in the inner Solar System; only a few percent of the building blocks of these two planets originated beyond Jupiter's orbit. A group of researchers led by the University of Münster (Germany) report these findings today in the journal *Science Advances*. They present the most comprehensive comparison to date of the isotopic composition of Earth, Mars and pristine building material from the inner and outer Solar System. Some of this material is today still found largely unaltered in meteorites. The results of the study have far-reaching consequences for our understanding of the process that formed the planets Mercury, Venus, Earth, and Mars. The theory postulating that the four rocky planets grew to their present size by accumulating millimetre-sized dust pebbles from the outer Solar System is not tenable.

Approximately 4.6 billion years ago in the early days of our Solar System, a disk of dust and gases orbited the young Sun. Two theories describe how in the course of millions of years the inner rocky planets formed from this original building material. According to the older theory, the dust in the inner Solar System agglomerated to ever larger chunks gradually reaching approximately the size of our Moon. Collisions of these planetary embryos finally produced the inner planets Mercury, Venus, Earth, and Mars. A newer theory, however, prefers a different growth process: millimetre-sized dust "pebbles" migrated from the outer Solar System towards the Sun. On their way, they were accreted onto the planetary embryos of the inner Solar System, and step by step enlarged them to their present size.

Both theories are based on theoretical models and computer simulations aimed at reconstructing the conditions and dynamics in the early Solar System; both describe a possible path of planet formation. But which one is right? Which process actually took place? To answer these questions, in their current study researchers from the University of Münster (Germany), the Observatoire de la Cote d'Azur (France), the California Institute of Technology (USA), the Natural History Museum Berlin (Germany), and the Free University of Berlin (Germany) determined the exact composition of the rocky planets Earth and Mars. "We wanted to find out whether the building blocks of Earth and Mars originated in the outer or inner Solar System," says Dr. Christoph Burkhardt of the University of Münster, the study's first author. To this end, the isotopes of the rare metal’s titanium, zirconium and molybdenum found in minute traces in the outer, silicate-rich layers of both planets provide crucial clues. Isotopes are different varieties of the same element, which differ only in the weight of their atomic nucleus.

Meteorites as a reference

Scientists assume that in the early Solar System these and other metal isotopes were not evenly distributed. Rather, their abundance depended on the distance from the Sun. They therefore hold valuable information about where in the early Solar System a certain body's building blocks originated.

As a reference for the original isotopic inventory of the outer and inner Solar System, the researchers used two types of meteorites. These chunks of rock generally found their way to Earth from the asteroid belt, the region between the orbits of Mars and Jupiter. They are considered to be largely pristine material

from the beginnings of the Solar System. While so-called carbonaceous chondrites, which can contain up to a few percent carbon, originated beyond Jupiter's orbit and only later relocated to the asteroid belt due to influence of the growing gas giants, their more carbon-depleted cousins, the non-carbonaceous chondrites, are true children of the inner Solar System.

The precise isotopic composition of Earth's accessible outer rock layers and that of both types of meteorites have been studied for some time; however, there have been no comparably comprehensive analyses of Martian rocks. In their current study, the researchers now examined samples from a total of 17 Martian meteorites, which can be assigned to six typical types of Martian rock. In addition, the scientists for the first time investigated the abundances of three different metal isotopes. The samples of Martian meteorites were first powdered and subjected to complex chemical pre-treatment. Using a multicollection plasma mass spectrometer at the Institute of Planetology at the University of Münster, the researchers were then able to detect tiny amounts of titanium, zirconium, and molybdenum isotopes. They then performed computer simulations to calculate the ratio in which building material found today in carbonaceous and non-carbonaceous chondrites must have been incorporated into Earth and Mars in order to reproduce their measured compositions. In doing so, they considered two different phases of accretion to account for the different history of the titanium and zirconium isotopes as well as of the molybdenum isotopes, respectively. Unlike titanium and zirconium, molybdenum accumulates mainly in the metallic planetary core. The tiny amounts still found today in the silicate-rich outer layers can therefore only have been added during the very last phase of the planet's growth.

The researchers' results show that the outer rock layers of Earth and Mars have little in common with the carbonaceous chondrites of the outer Solar System. They account for only about four percent of both planets' original building blocks. "If early Earth and Mars had mainly accreted dust grains from the outer Solar System, this value should be almost ten times higher," says Prof. Dr. Thorsten Kleine of the University of Münster, who is also director at the Max Planck Institute for Solar System Research in Göttingen. "We thus cannot confirm this theory of the formation of the inner planets," he adds.

Lost building material

But the composition of Earth and Mars does not exactly match the material of the non-carbonaceous chondrites either. The computer simulations suggest that another, different kind of building material must also have been in play. "The isotopic composition of this third type of building material as inferred by our computer simulations implies it must have originated in the innermost region of the Solar System," explains Christoph Burkhardt. Since bodies from such close proximity to the Sun were almost never scattered into the asteroid belt, this material was almost completely absorbed into the inner planets and thus does not occur in meteorites. "It is, so to speak, 'lost building material' to which we no longer have direct access today," says Thorsten Kleine.

The surprising find does not change the consequences of the study for theory of planet formation. "The fact that Earth and Mars apparently contain mainly material from the inner Solar System fits well with planet formation from the collisions of large bodies in the inner Solar System," concludes Christoph Burkhardt.

❖ A spacecraft has 'touched' the sun for the first time

Date: December 14, 2021
Source: American Physical Society

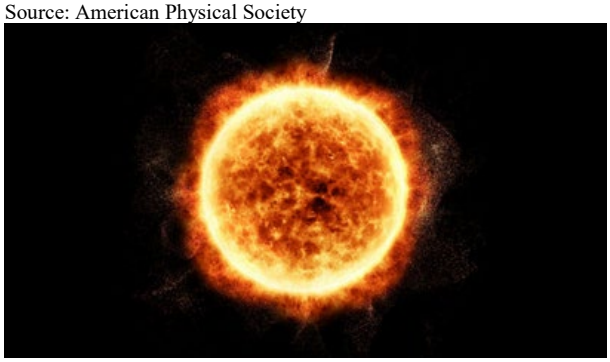


Illustration of sun (stock image).
Credit: © Kittiphat / stock.adobe.com

NASA's Parker Solar Probe reached the sun's extended solar atmosphere, known as the corona, and spent five hours there. The spacecraft is the first to enter the outer boundaries of our sun.

"This marks the achievement of the primary objective of the Parker mission and a new era for understanding the physics of the corona," said Justin C. Kasper, the first author, Deputy Chief Technology Officer at BWX Technologies, and a professor at the University of Michigan. The mission is led by

the Johns Hopkins University Applied Physics Laboratory (JHU/APL).

The probe made the first direct observations of what lies within the sun's atmosphere, measuring phenomena previously only estimated.

The sun's outer edge begins at the Alfvén critical surface: the point below which the sun and its gravitational and magnetic forces directly control the solar wind. Many scientists think that sudden reverses in the sun's magnetic field, called switchbacks, emerge from this area.

"The concept of sending spacecraft into the magnetized atmosphere of the sun -- sufficiently close that the magnetic energy is greater than both ion and electron kinetic and thermal energy -- predated NASA itself," said Kasper.

In 2018, NASA launched Parker Solar Probe with the goal of finally reaching the sun's corona and making humanity's first visit to a star.

This past April, the probe spent five hours below the Alfvén critical surface in direct contact with the sun's plasma. Below that surface, the pressure and energy of the sun's magnetic field was stronger than the pressure and energy of the particles. The spacecraft passed above and below the surface three separate times during its encounter. This is the first time a spacecraft has entered the solar corona and touched the atmosphere of the sun.

Surprisingly, the researchers discovered that the Alfvén critical surface is wrinkled. The data suggest that the largest and most distant wrinkle of the surface was produced by a pseudostreamer -- a large magnetic structure more than 40 degrees across, found back on the innermost visible face of the sun. It is not currently known why a pseudostreamer would push the Alfvén critical surface away from the sun.

Researchers noticed far fewer switchbacks below the Alfvén critical surface than above it. The finding could mean that switchbacks do not form within the corona. Alternatively, low rates of magnetic reconnection on the sun's surface could have pumped less mass into the observed wind stream, resulting in fewer switchbacks.

The probe also recorded some evidence of a potential power boost just inside the corona, which may point to unknown physics affecting heating and dissipation.

"We have been observing the sun and its corona for decades, and we know there is interesting physics going on there to heat and accelerate the solar wind plasma. Still, we cannot tell precisely what that physics is," said Nour E. Raouafi, the Parker Solar Probe Project Scientist at JHU/APL. "With Parker Solar Probe now flying into the magnetically-dominated corona, we will get the long-awaited insights into the inner workings of this mysterious region."

The observations took place during Parker Solar Probe's eighth encounter with the sun. All data is publicly available in the NASA PSP archive. Several previous studies predicted the probe would first pass within the sun's boundaries in 2021.

The fastest known object built by humans, Parker Solar Probe has made many new discoveries since its launch, including on explosions that create space weather and the dangers of super-speedy dust.

The new findings suggest that direct observations by spacecraft have much to illuminate about the physics of coronal heating and solar wind formation. Having achieved its goal of touching the sun, Parker Solar Probe will now descend even deeper into the sun's atmosphere and linger for longer periods of time.

According to Gary Zank, a coinvestigator on the probe's Solar Wind Electrons Alphas and Protons (SWEAP) instrument and a member of the National Academy of Sciences, "It is hard to overstate the significance of both the event and the observations made by Parker Solar Probe. For over 50 years, since the dawn of the space age, the heliospheric community has grappled with the unanswered problem of how the solar corona is heated to well over a million degrees to drive the solar wind. The first measurements of the sub-Alfvénic solar wind may represent the most major step forward in understanding the physics behind the acceleration of the solar wind since the formative model by Parker."

"This event is what many heliophysicists have dreamed about for most of their careers!" Zank added.

The results, published in *Physical Review Letters*, were announced in a press conference at the American Geophysical Union Fall Meeting 2021 on December 14.

- **Comets' heads can be green, but never their tails. After 90 years, we finally know why**

The team solved this mystery with the help of a vacuum chamber, a lot of lasers, and one powerful cosmic reaction.

Date: December 20, 2021
Source: University of New South Wales

(NASA Goddard)

Every so often, the Kuiper Belt and Oort Cloud throw galactic snowballs made up of ice, dust and rocks our way: 4.6-billion-year-old leftovers from the formation of the solar system.

These snowballs -- or as we know them, comets -- go through a colourful metamorphosis as they cross the sky, with many comets' heads turning a radiant green colour that gets brighter as they approach the Sun.

But strangely, this green shade disappears before it reaches the one or two tails trailing behind the comet.

Astronomers, scientists and chemists have been puzzled by this mystery for almost a century. In the 1930s, physicist Gerhard Herzberg theorised the phenomenon was due to sunlight destroying diatomic carbon (also known as dicarbon or C_2), a chemical created from the interaction between sunlight and organic matter on the comet's head -- but as dicarbon isn't stable, this theory has been hard to test.

A new UNSW Sydney-led study, published today in *Proceedings of the National Academy of Sciences (PNAS)*, has finally found a way to test this chemical reaction in a laboratory -- and in doing so, has proven this 90-year-old theory correct.

"We've proven the mechanism by which dicarbon is broken up by sunlight," says Timothy Schmidt, a chemistry professor at UNSW Science and senior author of the study.

"This explains why the green coma -- the fuzzy layer of gas and dust surrounding the nucleus -- shrinks as a comet gets closer to the Sun, and also why the tail of the comet isn't green."

The key player at the centre of the mystery, dicarbon, is both highly reactive and responsible for giving many comets their green colour. It's made up of two carbon atoms stuck together and can only be found in extremely energetic or low oxygen environments like stars, comets and the interstellar medium.

Dicarbon doesn't exist on comets until they get close to the Sun. As the Sun starts to warm the comet up, the organic matter living on the icy nucleus evaporates and moves to the coma. Sunlight then breaks up these larger organic molecules, creating dicarbon.

The UNSW-led team have now shown that as the comet gets *even closer* to the Sun, the extreme UV radiation breaks apart the dicarbon molecules it recently created in a process called 'photodissociation'. This process destroys the dicarbon before it can move far from the nucleus, causing the green coma to get brighter and shrink -- and making sure the green tinge never makes it into the tail.

This is the first time this chemical interaction has been studied here on Earth.

"I find incredible that someone in the 1930s thought this is probably what's happening, down to the level of detail of the mechanism of how it was happening, and then 90 years later, we find out it *is* what's happening," says Ms Jasmin Borsovszky, lead author of the study and former UNSW Science Honours student.

"Herzberg was an incredible physicist and went on to win a Nobel Prize for Chemistry in the 1970s. It's pretty exciting to be able to prove one of the things that he theorised."

Prof. Schmidt, who has been studying dicarbon for 15 years, says the findings help us better understand both dicarbon and comets.

"Dicarbon comes from the breakup of larger organic molecules frozen into the nucleus of the comet -- the sort of molecules that are the ingredients of life," he says.

"By understanding its lifetime and destruction, we can better understand how much organic material is evaporating off comets.

Discoveries like these might one day help us solve other space mysteries."

A laser show like no other

To solve this puzzle, the team needed to recreate the same galactic chemical process in a controlled environment on Earth.
They pulled this off with the help of a vacuum chamber, a lot of lasers, and one powerful cosmic reaction.
"First we had to make this molecule which is too reactive to store in a bottle," says Prof. Schmidt. "It's not something we could buy from the shops.
"We did this by taking a larger molecule, known as perchloroethylene or C_2Cl_4, and blasting off its chlorine atoms (Cl) with a high-powered UV laser."
The newly-made dicarbon molecules were sent travelling through a gas beam in a vacuum chamber, which was around two metres long.
The team then pointed another two UV lasers towards the dicarbon: one to flood it with radiation, the other to make its atoms detectable. The radiation hit ripped the dicarbon apart, sending its carbon atoms flying onto a speed detector.
By analysing the speed of these quickly-moving atoms, the team could measure the strength of the carbon bond to about one in 20,000 -- which is like measuring 200 metres to the nearest centimetre.
Ms Borsovszky says due to the complexity of the experiment it took nine months before they were able to make their first observation.
"We were about to give up," she says. "It took so long to make sure everything was precisely lined up in space and time.
"The three lasers were all invisible, so there was a lot of stabbing in the dark -- quite literally."
Prof. Schmidt says this is the first time anyone has ever observed this chemical reaction.
"It's extremely satisfying to have solved a conundrum that dates back to the 1930s."

Solving space mysteries

There are around 3700 known comets in the solar system, although it's suspected there could be billions more. On average, a comet's nucleus is a whopping 10 kilometres wide -- but its coma is often 1000 times bigger.
Bright comets can put on spectacular shows for those lucky enough to see them. But in the past, comets might have done more than that for Earth -- in fact, one of the theories about the origin of life is that comets once delivered the building blocks of life right to our doorstep.
"This exciting research shows us just how complex processes in interstellar space are," says Professor Martin van Kranendonk, a UNSW astrobiologist and geologist who was not involved in the study.
"Early Earth would have experienced a jumble of different carbon-bearing molecules being delivered to its surface, allowing for even more complex reactions to occur in the leadup to life."
Now that the case of the missing green tail in comets is solved, Prof. Schmidt, who specialises in space chemistry, wants to continue solving other space mysteries.
Next, he hopes to investigate diffuse interstellar bands: patterns of dark lines between stars that don't match any atom or molecule we know of.
"Diffuse interstellar bands are a pretty big unsolved mystery," he says. "We don't know why the light that's arriving on Earth often has nibbles taken out.
"This is just one more mystery in a huge inventory of bizarre things in space that we're yet to discover."

- **Are black holes and dark matter the same?**

Date: December 20, 2021
Source: University of Miami

Proposing an alternative model for how the universe came to be, a team of astrophysicists suggests that all black holes -- from those as tiny as a pin head to those covering billions of miles -- were created instantly after the Big Bang and account for all dark matter.
That's the implication of a study by astrophysicists at the University of Miami, Yale University, and the European Space Agency that suggests that black holes have existed since the beginning of the universe and that these primordial black holes could be as-of-yet unexplained dark matter. If proven true with data collected from this month's launch of the James Webb Space Telescope, the discovery may transform scientific understanding of the origins and nature of two cosmic mysteries: dark matter and black holes.

"Our study predicts how the early universe would look if, instead of unknown particles, dark matter was made by black holes formed during the Big Bang -- as Stephen Hawking suggested in the 1970s," said Nico Cappelluti, an assistant professor of physics at the University of Miami and first author of the study slated for publication in *The Astrophysical Journal.*

"This would have several important implications," continued Cappelluti, who this year expanded the research he began at Yale as the Yale Centre for Astronomy and Astrophysics Prize Postdoctoral Fellow. "First, we would not need 'new physics' to explain dark matter. Moreover, this would help us to answer one of the most compelling questions of modern astrophysics: How could supermassive black holes in the early universe have grown so big so fast? Given the mechanisms we observe today in the modern universe, they would not have had enough time to form. This would also solve the long-standing mystery of why the mass of a galaxy is always proportional to the mass of the super massive black hole in its centre."

Dark matter, which has never been directly observed, is thought to be most of the matter in the universe and act as the scaffolding upon which galaxies form and develop. On the other hand, black holes, which can be found at the centres of most galaxies, have been observed. A point in space where matter is so tightly compacted, they create intense gravity.

Co-authored by Priyamvada Natarajan, professor of astronomy and physics at Yale, and Günther Hasinger, director of science at the European Space Agency (ESA), the new study suggests that so-called primordial black holes of all sizes account for all black matter in the universe.

"Black holes of different sizes are still a mystery," Hasinger explained. "We don't understand how supermassive black holes could have grown so huge in the relatively short time available since the universe existed."

Their model tweaks the theory first proposed by Hawking and fellow physicist Bernard Carr, who argued that in the first fraction of a second after the Big Bang, tiny fluctuations in the density of the universe may have created an undulating landscape with "lumpy" regions that had extra mass. These lumpy areas would collapse into black holes.

That theory did not gain scientific traction, but Cappelluti, Natarajan, and Hasinger suggest it could be valid with some slight modifications. Their model shows that the first stars and galaxies would have formed around black holes in the early universe. They also propose that primordial black holes would have had the ability to grow into supermassive black holes by feasting on gas and stars in their vicinity, or by merging with other black holes.

"Primordial black holes, if they do exist, could well be the seeds from which all the supermassive black holes form, including the one at the centre of the Milky Way," Natarajan said. "What I find personally super exciting about this idea is how it elegantly unifies the two really challenging problems that I work on -- that of probing the nature of dark matter and the formation and growth of black holes -- and resolves them in one fell swoop."

Primordial black holes also may resolve another cosmological puzzle: the excess of infrared radiation, synced with X-ray radiation, that has been detected from distant, dim sources scattered around the universe. The study authors said growing primordial black holes would present "exactly" the same radiation signature.

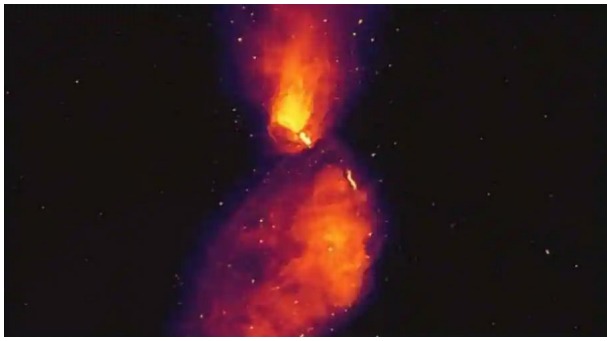
And, best of all, the existence of primordial black holes may be proven -- or disproven -- in the near future, courtesy of the Webb telescope scheduled to launch from French Guiana before the end of the year and the ESA-led Laser Interferometer Space Antenna (LISA) mission planned for the 2030s.

Developed by NASA, ESA, and the Canadian Space Agency to succeed the Hubble Space Telescope, the Webb can look back more than 13 billion years. If dark matter is comprised of primordial black holes, more stars and galaxies would have formed around them in the early universe, which is precisely what the cosmic time machine will be able to see.

"If the first stars and galaxies already formed in the so-called 'dark ages,' Webb should be able to see evidence of them," Hasinger said. LISA, meanwhile, will be able to pick up gravitational wave signals from early mergers of primordial black holes.

- **Astronomers capture black hole eruption spanning 16 times the full Moon in the sky**

Date: December 22, 2021
Source: International Centre for Radio Astronomy Research



Astronomers have produced the most comprehensive image of radio emission from the nearest actively feeding supermassive black hole to Earth.

The emission is powered by a central black hole in the galaxy Centaurus A, about 12 million light years away.

As the black hole feeds on in-falling gas, it ejects material at near light-speed, causing 'radio bubbles' to grow over hundreds of millions of years.

When viewed from Earth, the eruption from Centaurus A now extends eight degrees across the sky -- the length of 16 full Moons laid side by side.

It was captured using the Murchison Widefield Array (MWA) telescope in outback Western Australia.

The research was published today in the journal *Nature Astronomy.*

Lead author Dr Benjamin McKinley, from the Curtin University node of the International Centre for Radio Astronomy Research (ICRAR), said the image reveals spectacular new details of the radio emission from the galaxy.

"These radio waves come from material being sucked into the supermassive black hole in the middle of the galaxy," he said.

"It forms a disc around the black hole, and as the matter gets ripped apart going close to the black hole, powerful jets form on either side of the disc, ejecting most of the material back out into space, to distances of probably more than a million light years.

"Previous radio observations could not handle the extreme brightness of the jets and details of the larger area surrounding the galaxy were distorted, but our new image overcomes these limitations."

Centaurus A is the closest radio galaxy to our own Milky Way.

"We can learn a lot from Centaurus A in particular, just because it is so close and we can see it in such detail," Dr McKinley said.

"Not just at radio wavelengths, but at all other wavelengths of light as well.

"In this research we've been able to combine the radio observations with optical and x-ray data, to help us better understand the physics of these supermassive black holes."

Astrophysicist Dr Massimo Gaspari, from Italy's National Institute for Astrophysics, said the study corroborated a novel theory known as 'Chaotic Cold Accretion' (CCA), which is emerging in different fields.

"In this model, clouds of cold gas condense in the galactic halo and rain down onto the central regions, feeding the supermassive black hole," he said.

"Triggered by this rain, the black hole vigorously reacts by launching energy back via radio jets that inflate the spectacular lobes we see in the MWA image. This study is one of the first to probe in such detail the multiphase CCA 'weather' over the full range of scales," Dr Gaspari concluded.

Dr McKinley said the galaxy appears brighter in the centre where it is more active and there is a lot of energy.

"Then it's fainter as you go out because the energy's been lost and things have settled down," he said.

"But there are interesting features where charged particles have re-accelerated and are interacting with strong magnetic fields."

MWA director Professor Steven Tingay said the research was possible because of the telescope's extremely wide field-of-view, superb radio-quiet location, and excellent sensitivity.

"The MWA is a precursor for the Square Kilometre Array (SKA) -- a global initiative to build the world's largest radio telescopes in Western Australia and South Africa," he said.

"The wide field of view and, as a consequence, the extraordinary amount of data we can collect, means that the discovery potential of every MWA observation is very high. This provides a fantastic step toward the even bigger SKA."

- **Secret embraces of stars revealed by Alma**

Date: December 16, 2021
Source: Chalmers University of Technology

Unlike our Sun, most stars live with a companion. Sometimes, two come so close that one engulfs the other -- with far-reaching consequences. When a team of astronomers led by Chalmers University of Technology, Sweden, used the telescope Alma to study 15 unusual stars, they were surprised to find that they all recently underwent this phase. The discovery promises new insight on the sky's most dramatic phenomena -- and on life, death and rebirth among the stars.

Using the gigantic telescope Alma in Chile, a team of scientists led by Chalmers University of Technology studied 15 unusual stars in our galaxy, the Milky Way, the closest 5000 light years from Earth. Their measurements show that all the stars are double, and all have recently experienced a rare phase that is poorly understood, but is believed to lead to many other astronomical phenomena. Their results are published this week in the scientific journal *Nature Astronomy.*

By directing the antennas of Alma towards each star and measuring light from different molecules close to each star, the researchers hoped to find clues to their backstories. Nicknamed "water fountains," these stars were known to astronomers because of intense light from water molecules -- produced by unusually dense and fast-moving gas.

Located 5000 m above sea level in Chile, the Alma telescope is sensitive to light with wavelengths around one millimetre, invisible to human eyes, but ideal for looking through the Milky Way's layers of dusty interstellar clouds towards dust-enshrouded stars.

"We were extra curious about these stars because they seem to be blowing out quantities of dust and gas into space, some in the form of jets with speeds up to 1.8 million kilometres per hour. We thought we might find out clues to how the jets were being created, but instead we found much more than that," says Theo Khouri, first author of the new study.

Stars losing up to half their total mass

The scientists used the telescope to measure signatures of carbon monoxide molecules, CO, in the light from the stars, and compared signals from different atoms (isotopes) of carbon and oxygen. Unlike its sister molecule carbon dioxide, CO_2, carbon monoxide is relatively easy to discover in space, and is a favourite tool for astronomers.

"Thanks to Alma's exquisite sensitivity, we were able to detect the very faint signals from several different molecules in the gas ejected by these stars. When we looked closely at the data, we saw details that we really weren't expecting to see," says Theo Khouri.

The observations confirmed that the stars were all blowing off their outer layers. But the proportions of the different oxygen atoms in the molecules indicated that the stars were in another respect not as extreme as they had seemed, explains team member Wouter Vlemmings, astronomer at Chalmers University of Technology.

"We realised that these stars started their lives with the same mass as the Sun, or only a few times more. Now our measurements showed that they have ejected up to 50% of their total mass, just in the last few hundred years. Something really dramatic must have happened to them," he says.

A short but intimate phase

Why were such small stars come losing so much mass so quickly? The evidence all pointed to one explanation, the scientists concluded. These were all double stars, and they had all just been through a phase in which the two stars shared the same atmosphere -- one star entirely embraced by the other.

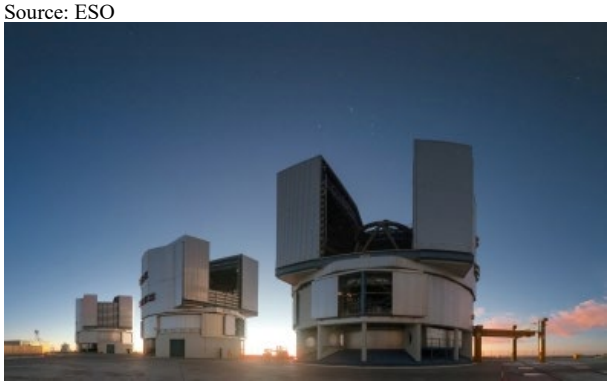
"In this phase, the two stars orbit together in a sort of cocoon. This phase, which we call a "common envelope" phase, is really brief, and only lasts a few hundred years. In astronomical terms, it's over in the blink of an eye," says team member Daniel Tafoya of Chalmers University of Technology.

Most stars in binary systems simply orbit around a common centre of mass. These stars, however, share the same atmosphere. It can be a life-changing experience for a star, and may even lead to the stars merging completely. Scientists believe that this sort of intimate episode can lead to some of the sky's most spectacular phenomena. Understanding how it happens could help answer some of

astronomers' biggest questions about how stars live and die, Theo Khouri explains.
"What happens to cause a supernova explosion? How do black holes get close enough to collide? What's makes the beautiful and symmetric objects we call planetary nebulae? Astronomers have suspected for many years that common envelopes are part of the answers to questions like these. Now we have a new way of studying this momentous but mysterious phase," he says.
Understanding the common envelope phase will also help scientists' study what will happen in the very distant future, when the Sun too will become a bigger, cooler star -- a red giant -- and engulf the innermost planets.
"Our research will help us understand how that might happen, but it gives me another, more hopeful perspective. When these stars embrace, they send dust and gas out into space that can become the ingredients for coming generations of stars and planets, and with them the potential for new life," says Daniel Tafoya.
Since the 15 stars seem to be evolving on a human timescale, the team plan to keep monitoring them with Alma and with other radio telescopes. With the future telescopes of the SKA Observatory, they hope to study how the stars form their jets and change their surroundings. They also hope to find more -- if there are any.
"Actually, we think the known "water fountains" could be almost the only systems of their kind in the whole of our galaxy. If that's true, then these stars really are the key to understanding the strangest, most wonderful and most important process that two stars can experience in their lives together," concludes Theo Khouri.

❖ Deepest images yet of Milky Way's supermassive black hole

Date: December 14, 2021
Source: ESO



The European Southern Observatory's Very Large Telescope Interferometer (ESO's VLTI) has obtained the deepest and sharpest images to date of the region around the supermassive black hole at the centre of our galaxy. The new images zoom in 20 times more than what was possible before the VLTI and have helped astronomers find a never-before-seen star close to the black hole. By tracking the orbits of stars at the centre of our Milky Way, the team has made the most precise measurement yet of the black hole's mass.
"We want to learn more about the black hole at the centre of the Milky Way, Sagittarius A*: How massive is it exactly? Does it rotate? Do stars around it behave exactly as we expect from Einstein's general theory of relativity? The best way to answer these questions is to follow stars on orbits close to the supermassive black hole. And here we demonstrate that we can do that to a higher precision than ever before," explains Reinhard Genzel, a director at the Max Planck Institute for Extra-terrestrial Physics (MPE) in Garching, Germany who was awarded a Nobel Prize in 2020 for Sagittarius A* research.
Genzel and his team's latest results, which expand on their three-decade-long study of stars orbiting the Milky Way's supermassive black hole, are published today in two papers in *Astronomy & Astrophysics*.
On a quest to find even more stars close to the black hole, the team, known as the GRAVITY collaboration, developed a new analysis technique that has allowed them to obtain the deepest and sharpest images yet of our Galactic Centre. "The VLTI gives us this incredible spatial resolution and with the new images we reach deeper than ever before. We are stunned by their amount of detail, and by the action and number of stars they reveal around the black hole," explains Julia Stadler, a researcher at the Max Planck Institute for Astrophysics in Garching who led the team's imaging efforts during her time at MPE.
Remarkably, they found a star, called S300, which had not been seen previously, showing how powerful this method is when it comes to spotting very faint objects close to Sagittarius A*.
With their latest observations, conducted between March and July 2021, the team focused on making precise measurements of stars as they approached the black hole. This includes the record-holder star S29, which made its nearest approach to the black hole in late May 2021. It passed it at a distance of just 13 billion kilometres, about 90 times the Sun-

Earth distance, at the stunning speed of 8740 kilometres per second. No other star has ever been observed to pass that close to, or travel that fast around, the black hole.
The team's measurements and images were made possible thanks to GRAVITY, a unique instrument that the collaboration developed for ESO's VLTI, located in Chile. GRAVITY combines the light of all four 8.2-metre telescopes of ESO's Very Large Telescope (VLT) using a technique called interferometry. This technique is complex, "but in the end you arrive at images 20 times sharper than those from the individual VLT telescopes alone, revealing the secrets of the Galactic Centre," says Frank Eisenhauer from MPE, principal investigator of GRAVITY.
"Following stars on close orbits around Sagittarius A* allows us to precisely probe the gravitational field around the closest massive black hole to Earth, to test General Relativity, and to determine the properties of the black hole," explains Genzel. The new observations, combined with the team's previous data, confirm that the stars follow paths exactly as predicted by General Relativity for objects moving around a black hole of mass 4.30 million times that of the Sun. This is the most precise estimate of the mass of the Milky Way's central black hole to date. The researchers also managed to fine-tune the distance to Sagittarius A*, finding it to be 27,000 light-years away.
To obtain the new images, the astronomers used a machine-learning technique, called Information Field Theory. They made a model of how the real sources may look, simulated how GRAVITY would see them, and compared this simulation with GRAVITY observations. This allowed them to find and track stars around Sagittarius A* with unparalleled depth and accuracy. In addition to the GRAVITY observations, the team also used data from NACO and SINFONI, two former VLT instruments, as well as measurements from the Keck Observatory and NOIRLab's Gemini Observatory in the US.
GRAVITY will be updated later this decade to GRAVITY+, which will also be installed on ESO's VLTI and will push the sensitivity further to reveal fainter stars even closer to the black hole. The team aims to eventually find stars so close that their orbits would feel the gravitational effects caused by the black hole's rotation. ESO's upcoming Extremely Large Telescope (ELT), under construction in the Chilean Atacama Desert, will further allow the team to measure the velocity of these stars with very high precision. "With GRAVITY+'s and the ELT's powers combined, we will be able to find out how fast the black hole spins," says Eisenhauer. "Nobody has been able to do that so far."

- **Super-bright stellar explosion is likely a dying star giving birth to a black hole or neutron star**

The discovery, based on a usual event dubbed 'the Cow,' may offer astronomers a new way to spot infant compact objects
Date: December 13, 2021
Source: Massachusetts Institute of Technology
In June of 2018, telescopes around the world picked up a brilliant blue flash from the spiral arm of a galaxy 200 million light years away. The powerful burst appeared at first to be a supernova, though it was much faster and far brighter than any stellar explosion scientists had yet seen. The signal, procedurally labelled AT2018cow, has since been dubbed simply "the Cow," and astronomers have catalogued it as a fast blue optical transient, or FBOT -- a bright, short-lived event of unknown origin.
Now an MIT-led team has found strong evidence for the signal's source. In addition to a bright optical flash, the scientists detected a strobe-like pulse of high-energy X-rays. They traced hundreds of millions of such X-ray pulses back to the Cow, and found the pulses occurred like clockwork, every 4.4 milliseconds, over a span of 60 days.
Based on the frequency of the pulses , the team calculated that the X-rays must have come from an object measuring no more than 1,000 kilometres wide, with a mass smaller than 800 suns. By astrophysical standards, such an object would be considered compact, much like a small black hole or a neutron star.
Their findings, published today in the journal *Nature Astronomy*, strongly suggest that AT2018cow was likely a product of a dying star that, in collapsing, gave birth to a compact object in the form of a black hole or neutron star. The new born object continued to devour surrounding material, eating the star from the inside -- a process that released an enormous burst of energy.
"We have likely discovered the birth of a compact object in a supernova," says lead author Dheeraj "DJ" Pasham, a research scientist in MIT's Kavli Institute for Astrophysics and Space Research. "This happens in normal supernovae, but we haven't

seen it before because it's such a messy process. We think this new evidence opens possibilities for finding baby black holes or baby neutron stars."

"The core of the Cow"

AT2018cow is one of many "astronomical transients" discovered in 2018. The "cow" in its name is a random coincidence of the astronomical naming process (for instance, "aaa" refers to the very first astronomical transient discovered in 2018). The signal is among a few dozen known FBOTs, and it is one of only a few such signals that have been observed in real-time. Its powerful flash -- up to 100 times brighter than a typical supernova -- was detected by a survey in Hawaii, which immediately sent out alerts to observatories around the world.

"It was exciting because loads of data started piling up," Pasham says. "The amount of energy was orders of magnitude more than the typical core collapse supernova. And the question was, what could produce this additional source of energy?"

Astronomers have proposed various scenarios to explain the super-bright signal. For instance, it could have been a product of a black hole born in a supernova. Or it could have resulted from a middle-weight black hole stripping away material from a passing star. However, the data collected by optical telescopes haven't resolved the source of the signal in any definitive way. Pasham wondered whether an answer could be found in X-ray data.

"This signal was close and also bright in X-rays, which is what got my attention," Pasham says. "To me, the first thing that comes to mind is, some really energetic phenomenon is going on to generate X-rays. So, I wanted to test out the idea that there is a black hole or compact object at the core of the Cow."

Finding a pulse

The team looked to X-ray data collected by NASA's Neutron Star Interior Composition Explorer (NICER), an X-ray-monitoring telescope aboard the International Space Station. NICER started observing the Cow about five days after its initial detection by optical telescopes, monitoring the signal over the next 60 days. This data was recorded in a publicly available archive, which Pasham and his colleagues downloaded and analysed.

The team looked through the data to identify X-ray signals emanating near AT2018cow, and confirmed that the emissions were not from other sources such as instrument noise or cosmic background phenomena. They focused on the X-rays and found that the Cow appeared to be giving off bursts at a frequency of 225 hertz, or once every 4.4 milliseconds. Pasham seized on this pulse, recognizing that its frequency could be used to directly calculate the size of whatever was pulsing. In this case, the size of the pulsing object cannot be larger than the distance that the speed of light can cover in 4.4 milliseconds. By this reasoning, he calculated that the size of the object must be no larger than 1.3×10^8 centimetres, or roughly 1,000 kilometres wide.

"The only thing that can be that small is a compact object -- either a neutron star or black hole," Pasham says.

The team further calculated that, based on the energy emitted by AT2018cow, it must amount to no more than 800 solar masses.

"This rules out the idea that the signal is from an intermediate black hole," Pasham says.

Apart from pinning down the source for this particular signal, Pasham says the study demonstrates that X-ray analyses of FBOTs and other ultrabright phenomena could be a new tool for studying infant black holes.

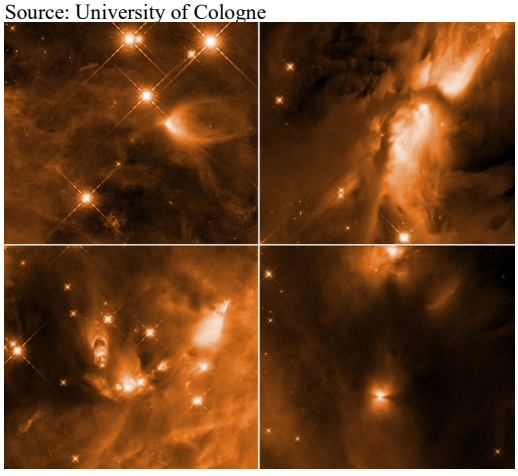
"Whenever there's a new phenomenon, there's excitement that it could tell something new about the universe," Pasham says. "For FBOTs, we have shown we can study their pulsations in detail, in a way that's not possible in the optical. So, this is a new way to understand these new born compact objects."

This research was supported, in part, by NASA.

Video explaining the new discovery from AT2018cow:
https://www.youtube.com/watch?v=NSZIewPb0zU

- **Infant stars identified at the centre of our galaxy**

Date: December 10, 2021
Source: University of Cologne



What was previously identified as a gas and dust cloud at the centre of our galaxy actually consists of three very young stars. That is the result of a new study led by scientists from the University of Cologne's Institute of Astrophysics. The European Southern Observatory's Very Large Telescope (VLT) - a telescope with mirror diameters of 8.20 metres on the summit of Cerro Paranal in Chile - provided the data for the study, which has appeared in *The Astrophysical Journal.* The stars began to form less than 1 million years ago, which is very young in astrophysical terms. By comparison, our sun is just under 5 billion years old.

In 2011, an object was found by means of the infrared data measured by the Very Large Telescope, promising to reveal an unprecedented process at the centre of our galaxy. Based on a multi-wavelength analysis, scientists determined that it must be a cloud of gas and dust, which was named G2. The interaction with the black hole at the centre of our galaxy, SgrA*, should have torn G2 apart and caused proverbial fireworks. The researchers assumed that when G2 collided with SgrA*, various processes would cause the gas and dust to make the black hole flare up. But that did not happen.

In addition, there were other factors that gave astronomers around the world a headache and fuelled controversial discussions. Studies showed that the temperature of G2 is almost twice as high as that of surrounding dust sources. One possible explanation for G2's temperature is the extreme number of stars at the centre of our galaxy. So these stars could have heated up G2. The only question is why all other known dust sources at the centre of the galaxy show a much lower temperature. The black hole, SgrA*, was also ruled out as a heat source. The temperature of G2 should have increased the closer the supposed dust cloud came to the black hole - like we would feel if we approached a radiator. However, the temperature remained constant over a long period of time, although the distance to the black hole varied. The more closely G2 was observed around the world, the more it became apparent that the cosmic object had to be more than just a cloud of gas and dust.

The new results show that G2 actually consists of three individual stars. 'We had the opportunity to observe the centre of our galaxy ourselves several times with the Very Large Telescope. Together with the data from the Southern Observatory archive, we were able to cover a period from 2005 to 2019,' said lead author Dr Florian Peißker from the Institute of Astrophysics. The unusual structure of the data was also helpful in locating G2. Each pixel of the captured image has an associated spectrum that covers a very specific and detailed waveband. For the scientists, this offers an enormous level of detail. 'That G2 actually consists of three evolving young stars is sensational. Never before have stars younger than the ones found been observed around SgrA*,' Peißker said.

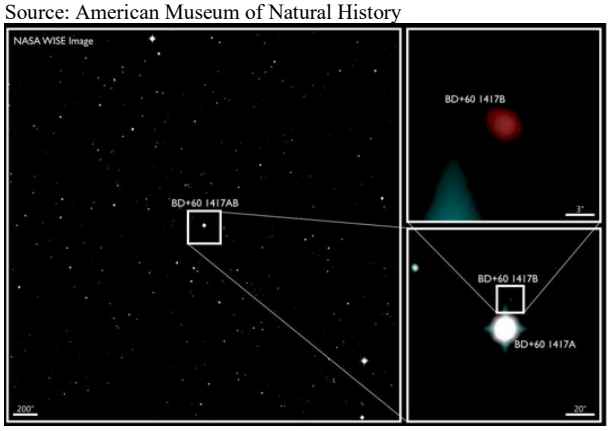
The results open the door to many more fascinating research questions - for example where these young stars come from. The radiation-intensive environment of a supermassive black hole is not necessarily the best place to produce young stars. Peißker concludes, 'The new results provide unique insights into how black holes work. We can use the environment of SgrA* as a blueprint to learn more about the evolution and processes of other galaxies in completely different corners of our Universe.'

- **Citizen scientists find young-Jupiter-like object missed by previous exoplanet searches**

New study finds a world about 146 light years away that's not quite a planet, not quite a brown dwarf

Date: December 9, 2021

Source: American Museum of Natural History



At left, the NASA WISE image of the BD+60 1417AB system. At right bottom

Citizen scientists have discovered a new object orbiting a Sun-like star that had been missed by previous searches. The object is very distant from its host star -- more than 1,600 times farther than the Earth is from the Sun -- and is thought to be a large planet or a small brown dwarf, a type of object that is not massive enough to burn hydrogen like true

stars. Details about the new world are published today in *The Astrophysical Journal*.
"This star had been looked at by more than one campaign searching for exoplanet companions. But previous teams looked really tight, really close to the star," said lead author Jackie Faherty, senior scientist in the American Museum of Natural History's Department of Astrophysics and co-founder of the citizen science project Backyard Worlds: Planet 9, which led to the object's discovery. "Because citizen scientists really liked the project, they found an object that many of these direct imaging surveys would have loved to have found, but they didn't look far enough away from its host."

The Backyard Worlds project lets volunteers search through nearly five years of digital images taken from NASA's Wide-field Infrared Survey Explorer (WISE) mission to try to identify new worlds inside and outside of our solar system. If an object close to Earth is moving, it will appear to "jump" in the same part of the sky over the years, similar to an object "moving" in a flipbook. Users can then flag these objects for further study by scientists.

In 2018, Backyard Worlds participant Jörg Schümann, who lives in Germany, alerted scientists to a new co-moving system: an object that appeared to be moving with a star. After confirming the system's motion, scientists used telescopes in California and Hawai'i to observe the star and object separately and were immediately excited by what they saw.

The new object is young and has a low mass, between 10 and 20 times the mass of Jupiter. This range overlaps with an important cut off point -- 13 times the mass of Jupiter -- which is sometimes used to distinguish planets from brown dwarfs. But scientists still aren't sure how heavy planets can be, which can make relying on this cut off challenging. "We don't have a very good definition of the word 'planet,'" said Faherty.

Another defining feature is how they form: planets form from material gathering in disks around stars, while brown dwarfs are born from the collapse of giant clouds of gas, similar to how stars form. But the physical properties of this new object do not provide any clues to its formation. "There are hints that maybe it's more like an exoplanet, but there's nothing conclusive yet. However, it is an outlier," said Faherty.

What surprised the team the most is the new object's relationship to its host star. The object is farther away from the star than expected based on its comparatively low mass -- over 1,600 times farther than the Earth is from the Sun. Few objects with such different masses from their host star have been found this far apart.

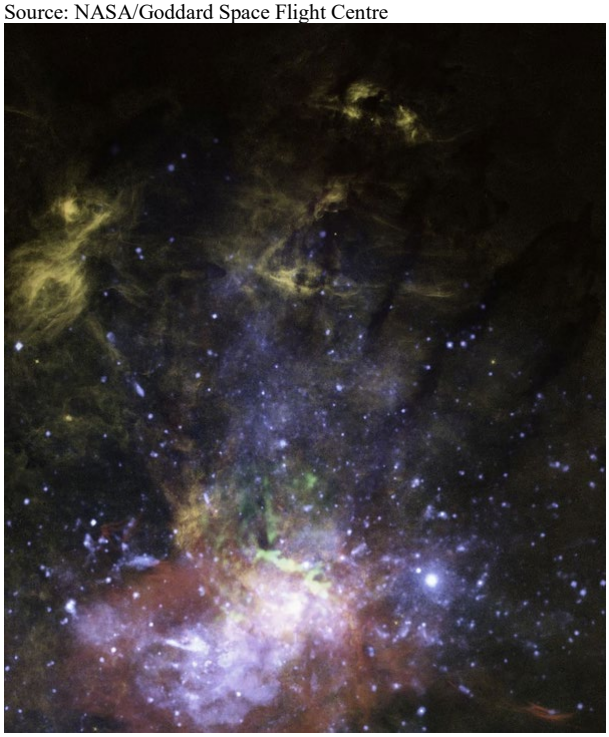
Ultimately, this discovery may help scientists get a better sense of how solar systems form, which is crucial to understanding the origins of life in the universe. "You had an exoplanet community just staring so close to it," said Faherty. "And we just pulled out a little, and we found an object. That makes me excited about what we might be missing in giant planets that might exist around these stars," said Faherty. "Sometimes, you need to broaden your scope."

Other authors on the study include Johanna M. Vos, Daniella C. Bardalez Gagliuffi, Austin Rothermich, and Andrew Ayala from the American Museum of Natural History; Jonathan Gagné from the University of Montreal; Mark Popinchalk from the American Museum of Natural History and the City University of New York; Adam J. Burgasser, Christian Aganze, Chih-Chun Hsu, Roman Gerasimov, and Christopher A. Theissen from the University of California, San Diego; Adam C. Schneider from the U.S. Naval Observatory and George Mason University; J. Davy Kirkpatrick and Federico Marocco from the California Institute of Technology; Aaron M. Meisner from NSF's National Optical-Infrared Astronomy Research Laboratory; Marc J. Kuchner from NASA Goddard Space Flight Centre; Dan Caselden from Gigamon Applied Threat Research; Eileen C. Gonzales from Cornell University; Sarah L. Casewell from the University of Leicester; John H. Debes from the Space Telescope Science Institute; William J. Cooper from the University of Hertfordshire and the National Institute for Astrophysics in Italy, and R. L. Smart from the National Institute for Astrophysics in Italy.

This research was supported in part by NASA Astrophysics Data Analysis Program grant #s NNH17AE75I and 80NSSC20K0452 as well as NASA grant 2017-ADAP17-0067, the National Science Foundation grant #s 2007068, 2009136, and 2009177, and the Heising-Simons Foundation.

❖ Mini-jet found near Milky Way's supermassive black hole

Date: December 9, 2021
Source: NASA/Goddard Space Flight Centre



A mini-jet extends from the supermassive black hole at the centre of the Milky Way galaxy. (Image credit: NASA/ESA/Gerald Cecil (UNC-Chapel Hill)/Joseph DePasquale (STSc

Our Milky Way's central black hole has a leak. This supermassive black hole looks like it still has the vestiges of a blowtorch-like jet dating back several thousand years. NASA's Hubble Space Telescope hasn't photographed the phantom jet but has helped find circumstantial evidence that it is still pushing feebly into a huge hydrogen cloud and then splattering, like the narrow stream from a hose aimed into a pile of sand.

This is further evidence that the black hole, with a mass of 4.1 million Suns, is not a sleeping monster but periodically hiccups as stars and gas clouds fall into it. Black holes draw some material into a swirling, orbiting accretion disk where some of the infalling material is swept up into outflowing jets that are collimated by the black hole's powerful magnetic fields. The narrow "searchlight beams" are accompanied by a flood of deadly ionizing radiation.

"The central black hole is dynamically variable and is currently powered down," said Gerald Cecil of the University of North Carolina in Chapel Hill. Cecil pieced together, like a jigsaw puzzle, multiwavelength observations from a variety of telescopes that suggest the black hole burps out mini-jets every time it swallows something hefty, like a gas cloud. His multinational team's research has just been published in the *Astrophysical Journal.*

In 2013 evidence for a stubby southern jet near the black hole came from X-rays detected by NASA's Chandra X-ray Observatory and radio waves detected by the Jansky Very Large Array telescope in Socorro, New Mexico. This jet too appears to be ploughing into gas near the black hole.

Cecil was curious if there was a northern counter-jet as well. He first looked at archival spectra of such molecules as methyl alcohol and carbon monosulfide from the ALMA Observatory in Chile (Atacama Large Millimetre/Submillimetre Array), which uses millimetre wavelengths to peer through the veils of dust between us and the galactic core. ALMA reveals an expanding, narrow linear feature in molecular gas that can be traced back at least 15 light-years to the black hole.

By connecting the dots, Cecil next found in Hubble infrared-wavelength images a glowing, inflating bubble of hot gas that aligns to the jet at a distance of at least 35 light-years from the black hole. His team suggests that the black hole jet has ploughed into it, inflating the bubble. These two residual effects of the fading jet are the only visual evidence of it impacting molecular gas.

As it blows through the gas the jet hits material and bends along multiple streams. "The streams percolate out of the Milky Way's dense gas disk," said co-author Alex Wagner of Tsukuba University in Japan. "The jet diverges from a pencil beam into tendrils, like that of an octopus." This outflow creates a series of expanding bubbles that extend out to at least 500 light-years. This larger "soap bubble" structure has been mapped at various wavelengths by other telescopes.

Wagner and Cecil next ran supercomputer models of jet outflows in a simulated Milky Way disk, which reproduced the observations. "Like in archaeology, you dig and dig to find older and older artefacts until you come upon remnants of a grand civilization," said Cecil. Wagner's conclusion: "Our central black hole clearly surged in luminosity at least 1 millionfold in the last million years. That sufficed for a jet to punch into the Galactic halo."

Previous observations by Hubble and other telescopes found evidence that the Milky Way's black hole had an outburst about 2-4 million years ago. That was energetic enough to create an immense pair of bubbles towering

above our galaxy that glow in gamma-rays. They were first discovered by NASA's Fermi Gamma-ray Space Telescope in 2010 and are surrounded by X-ray bubbles that were discovered in 2003 by the ROSAT satellite and mapped fully in 2020 by the eROSITA satellite.

Hubble ultraviolet-light spectra have been used to measure the expansion velocity and composition of the ballooning lobes. Hubble spectra later found that the burst was so powerful that it lit up a gaseous structure, called the Magellanic stream, at about 200,000 light-years from the galactic centre. Gas is glowing from that event even today.

To get a better idea of what's going on, Cecil looked at Hubble and radio images of another galaxy with a black hole outflow. Located 47 million light-years away, the active spiral galaxy NGC 1068 has a string of bubble features aligned along an outflow from the very active black hole at its centre. Cecil found that the scales of the radio and X-ray structures emerging from both NGC 1068 and our Milky Way are very similar. "A bow shock bubble at the top of the NGC 1068 outflow coincides with the scale of the Fermi bubble start in the Milky Way. NGC 1068 may be showing us what the Milky Way was doing during its major power surge several million years ago."

The residual jet feature is close enough to the Milky Way's black hole that it would become much more prominent only a few decades after the black hole powers up again. Cecil notes that "the black hole need only increase its luminosity by a hundredfold over that time to refill the jet channel with emitting particles. It would be cool to see how far the jet gets in that outburst. To reach into the Fermi gamma-ray bubbles would require that the jet sustain for hundreds of thousands of years because those bubbles are each 50,000 light years across!"

The anticipated images of the black hole's shadow made with the National Science Foundation's Event Horizon Telescope may reveal where and how the jet is launched.

Video of mini jet near the Milky Way's supermassive black hole: https://www.youtube.com/watch?v=zxqQ4G0NOhI&t=144s